In presenting the dissertation as a partial fulfillment of the requirements for an advanced degree from the Georgia Institute of Technology, I agree that the Library of the Institution shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to copy from, or to publish from, this dissertation may be granted by the professor under whose direction it was written, or, in his absence, by the dean of the Graduate Division when such copying or publication is solely for scholarly purposes and does not involve potential financial gain. It is understood that any copying from, or publication of, this dissertation which involves potential financial gain will not be allowed without written permission.

THE EFFECT OF MICA CONTENT ON THE COMPRESSIBILITY OF SAPROLITES

A THESIS

Presented to

The Faculty of the Graduate Division

by

Samuel P. Clemence

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Civil Engineering

Georgia Institute of Technology

November, 1963

THE EFFECT OF MICA CONTENT ON

THE COMPRESSIBILITY OF SAPROLITES

Approved:

Date approved by Chairman: 3/6/64

ACKNOWLEDGMENTS

Appreciation is expressed to Professor G. F. Sowers for his encouragement and advice while serving as advisor for this research. The author also wishes to express his gratitude to Dr. Aleksandar B. Vesić and Dr. H. W. Straley, III for their helpful criticisms and suggestions while serving as members of the reading committee.

Acknowledgment is also made to Robert and Company Associates for granting a fellowship and thus making this year of graduate study possible.

The author would also like to express gratitude to his parents for their patience and help.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

SUMMARY

The determination of the effect of mica content on the compressibility of micaceous soils was the objective of this study. The soils used in the tests were saprolites, which are residual soils derived from the in-place weathering of rock and which retain the appearance and structure of the original rock. The experimental work consisted of separating the mica from the soil samples and consolidation tests on soils containing varying amounts of mica.

The soil samples used in the tests were undisturbed samples obtained from the Piedmont region of the southeastern United States. All the soils used in the tests can be described as micaceous silty sands, with little or no plasticity, and are classified as SM and SM-SW by the Bureau of Public Roads Classification System. The mica content of the soil samples ranged from 8 to 40 per cent by weight.

Although experiments were undertaken to determine if an empirical relation could be found between the mica content and the compression characteristics of the soil, it was found that there were so many other factors influencing the compression of a soil that a definite relation between the mica content and the compressibility was obscure.

The results of the consolidation tests show that on semi-logarithmic coordinates, the pressure-void ratio curves for the samples containing a high percentage of mica are curved throughout the range of pressures applied to them. The virgin curve portion of the pressure-

void ratio curve is not a straight line, as is the case for normally consolidated clays.

The indicated preconsolidation loads inferred from the shapes of the pressure-void ratio curves for the soils were quite variable, with large differences occurring even for samples taken at the same site and at approximately the same depths.

The average relation between the initial void ratio and the compression index was found to be in agreement with previous results. However it was found that a family of curves exists for differing mica contents. The compression index increased with increasing mica content, and a series of curves for varying mica contents was defined similar to the shape of the curve found by previous investigations. The elastic rebound or decompression curves of the soil were more curved for those containing a high percentage of mica, while the soils with a lower percentage had rather flat curves.

The initial or instantaneous compression of the soil was much greater for the samples containing a high mica content. The secondary compression of the soils increased with increasing mica content.

This research suggests that while there are many factors influencing the compressibility of soils, mica content is an important consideration and further testing should be undertaken to more clearly define the exact effects of the mica content. The development of a standard laboratory procedure for the separation of mica from soil is recommended. The study of the effect of the mica content on the secondary compression of a soil should be investigated.

CHAPTER I

INTRODUCTION

The increasing industrial development of the southeastern United States and other areas of the world where there in an abundance of residual soils has given impetus to the study of the engineering properties of these soils. The construction of large industrial plants and the building of more highways in these areas has increased, and the problems encountered in foundations and subgrades are unique to these soils. A term commonly used to define the soils found in these areas is "saprolites," which is defined in the Glossary of Selected Geologic Terms (1) as:

> A general name for clay, silt or other earth material that has been derived by disintegration and decomposition in place and has not been transported. The color is commonly red or brown and some evidences of the structure and texture of the parent material may still be evident.

Several members of the mica family of minerals are commonly found in the saprolite soils of the Piedmont Region. The presence of mica in a soil has a definite effect on the physical properties and character of the soil. The flaky or scalelike shape of the mica minerals is responsible for altering the shear strength and compressibility of the soil.

The importance of the mica content of a soil was first recognized by Terzaghi, in 1925. Terzaghi mentioned the four most important factors which influence the behavior of sands to be grain size, uniformity, volume of voids and mica content (see reference 2). The effect of mica content on compressibility was first experimentally investigated in 1926 by Gilboy at the Massachusetts Institute of Technology under the direction of Terzaghi (2). The experiments of Gilboy aroused considerable interest in the subject at that time, but for the next 35 years very little was written on the subject and no experimental work was done. In the past several years, however, experimental investigations at the University of Virginia (3) and at Lehigh University (4) have been undertaken to determine the effect of mica content on the shear strength and compressibility of both artificially reconstituted and compacted micaceous soils.

The purpose of this research was to investigate the influence of mica content on the compressibility characteristics of naturally micaceous soils in an undisturbed state. The effect of mica content was examined by comparing the consolidation of soils with different percentages of mica and comparing these soils on the basis of the coefficient of consolidation and the compression index. The influence of mica content on the elastic rebound of the soils was also studied.

CHAPTER II

REVIEW OF THE LITERATURE

The first article appearing in the literature on the subject of mica content and its effect on the compressibility of soils was by Gilboy. This paper (2) was a resumé of an experimental investigation undertaken as a master's thesis at the Massachusetts Institute of Technology. The experiments consisted of consolidation tests on mixtures of mica and wind worn dune sand composed of well rounded quartz particles. The specific conclusions reached from these tests were:

(1) Other things being equal, the initial void ratio of compacted uncompressed granular masses increases with increasing mica content.

(2) Other things being equal, the greater the proportion of flat grains in a granular mass, the greater is the compressibility of the mass, and the more marked is the elastic expansion after removal of load.

The author goes on to discuss at length the similarity of the structure of the mica particles and those of the clay minerals and suggests that the consolidation of clay could be attributed to the elastic deformation of the scalelike particles present in the clay minerals. The article was followed by a discussion by four engineers who all agreed that the shape of the particles present in a soil have considerable influence on the compressibility of a soil; however, several of the discussions took serious objection to the idea that the scale-like shape of the clay minerals was the sole cause for their compressibility.

The results of Gilboy's experiments are referred to in several textbooks (5,6), which are general treatises on the subject of soil mechanics. In 1950, Terzaghi (7) suggested the use of a grain-shape factor, F_s being the ratio between the weight of the flaky particles and the dry weight of the soil. With an increasing value of F_s, both the initial void ratio and the compression index c_c would increase.

At the 42nd Annual Meeting of the Highway Research Board, Washington, D. C., January 7-11, 1963, two research papers were presented which were the results of experimental investigations on micaceous soils of the Piedmont Region of the United States. Tate and Larew presented the results of repeated load triaxial tests on laboratory compacted samples of micaceous soils conducted to determine the amount of elastic or resilient rebound for the soil samples (3). The results from this study established the fact that elastic rebound is dependent upon the amount of mica present in the soil and the orientation of the mica flakes. The investigators also concluded that the method of compaction influences the orientation of the mica particles thereby influencing the elastic rebound of the soil. These studies are being continued at the University of Virginia to find a practical way of reducing the amount of rebound of micaceous soils so that they may be used in a wider scale in highway construction. The other paper presented at the meeting was by McCarthey and Leonard and was a report of laboratory tests on compacted and artificially reconstituted micaceous soils. The changes in compressibility caused by increasing mica content were investigated. Differences caused by substituting differing mica sizes, and variation of density and of moisture content were also studied.

There were several conclusions reached from this investigation. The writers found that the presence of mica has a pronounced effect on the density of a soil, also the effect of less than a 10 per cent mica content is very minor on the density of a soil. Concerning the effect on the compressibility of soils, the increase of mica content was found to increase the compressibility of the soil. An empirical equation based on the percentage of mica present, was developed to define the compression index of non-plastic micaceous soils compacted to the modified Proctor density.

Sowers at the Georgia Institute of Technology has written several articles (8,9) concerning soil conditions in the Piedmont Region in which he points out that the mica content of a soil has effects on the initial void ratio, compressibility, and on the secondary compression. He also indicates that well compacted fills of micaceous sandy silts and silty sands make satisfactory foundation material, but he cautions that high densities must be obtained.

All the previous investigations have been concerned with the compressibility of compacted micaceous soils or artificially reconstituted mixtures of mica and soil. This present study approaches this problem from the standpoint of undisturbed soils whose natural mica content is high.

CHAPTER III

INSTRUMENTATION AND EQUIPMENT

Consolidation Tests

The tests were conducted using four floating-ring consolidometers, 1.10 inches high and 2.375 inches in diameter. The consolidometers were mounted in a lever type loading apparatus (Figures 1 and 2) and subjected to loads up to 32,000 psf or 222 psi.

Vertical deflection was measured by micrometer dial gauges having a smallest division of 0.001 inches.

Mica Content Determination

The percentage of mica in each sample was determined by the use of three processes. The equipment used will be described in the order of testing procedure.

Magnetic Separation. A high intensity induced-roll magnetic separator was used for the primary step in separation of the mica. The separator used throughout the tests was a Carpco Laboratory Model M-127 (10) high intensity magnetic separator. This device is capable of producing a field of 27,000 Gausses in the airgap of the separating device, which is a sufficient force field to separate the weakly magnetic mica particles from the non-magnetic constituents of the soil (Figure 3).

Heavy Fluid Separation. The principle of heavy fluid flotation was used in the secondary step of the separation of mica. The heavy fluids used were tetrabromoethane (specific gravity of 2.96 at 25 C^o)

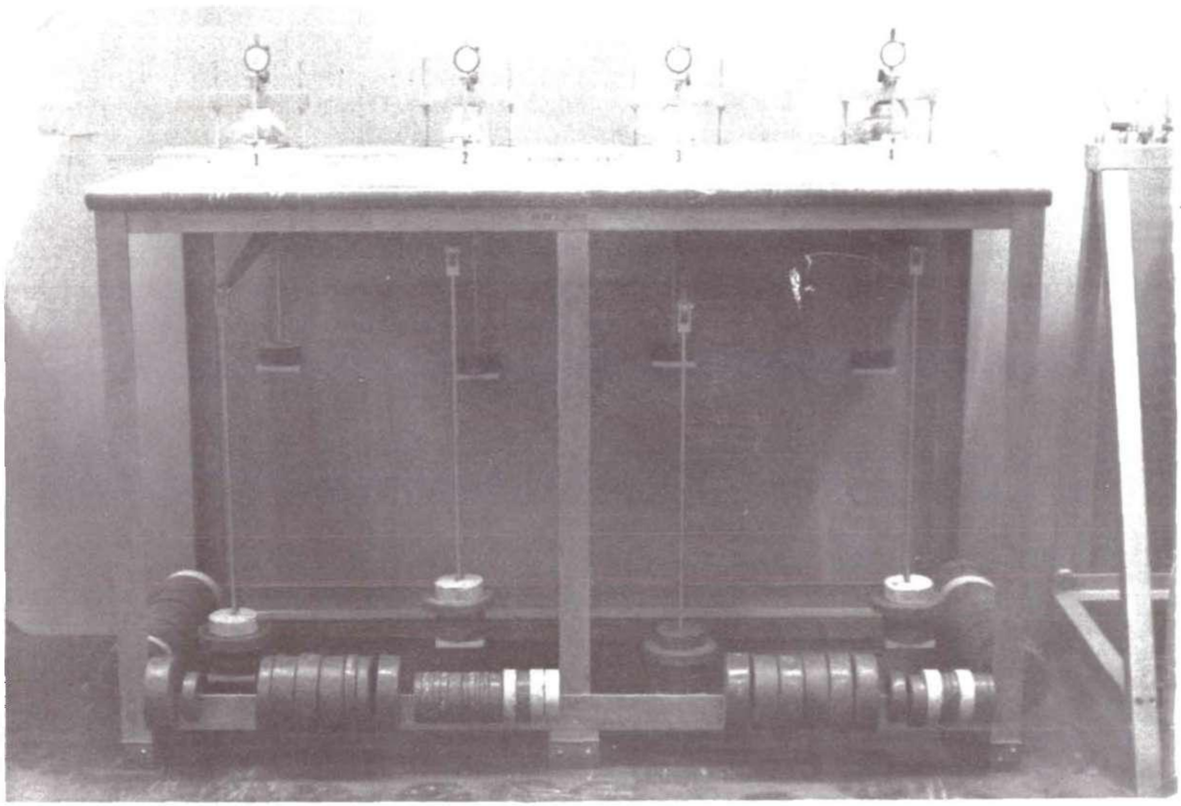

Figure 1. Photograph. The Consolidometer Loading Apparatus

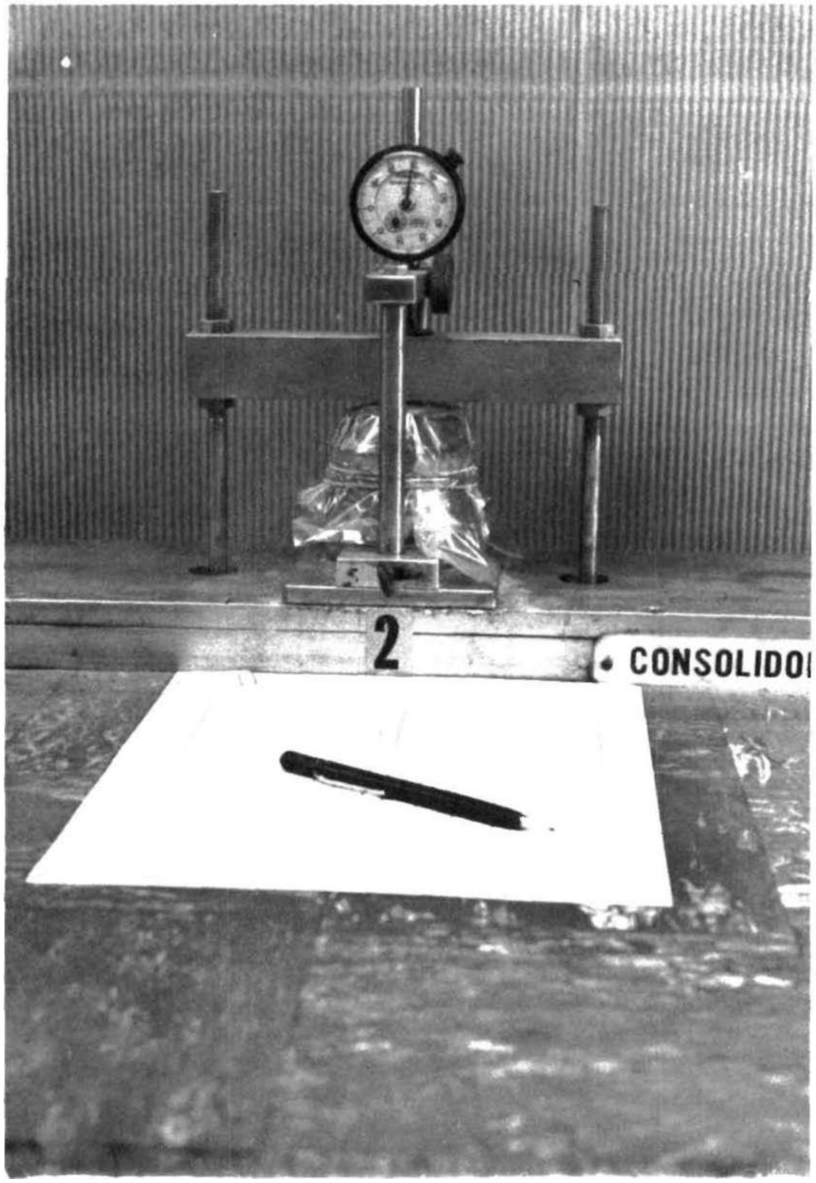

Figure 2. Photograph. The Floating Ring Consolidometer.

and tetrachloroethane (specific gravity of 1.59 at 25 C^o). The tetrachloroethane was used as a diluent to achieve the proper specific gravity.

The separatory device consisted of a glass funnel with a Teflon plastic valve in the stem set on a supporting stand as pictured on Figure 4. After separation, the sample was recovered by passing the fluid through high speed filter paper into a graduated cylinder.

Petrographic Microscope. A compound polarizing microscope with a micrometer disc inserted in the eyepiece in place of the hairline was used to determine the mica content of the soil finer than 0.074 mm (No. 200 sieve). The micrometer disc contained a net-grating and the squares were calibrated using the stage micrometer on the microscope. The samples were placed on glass slides and suspended in oil for observation.

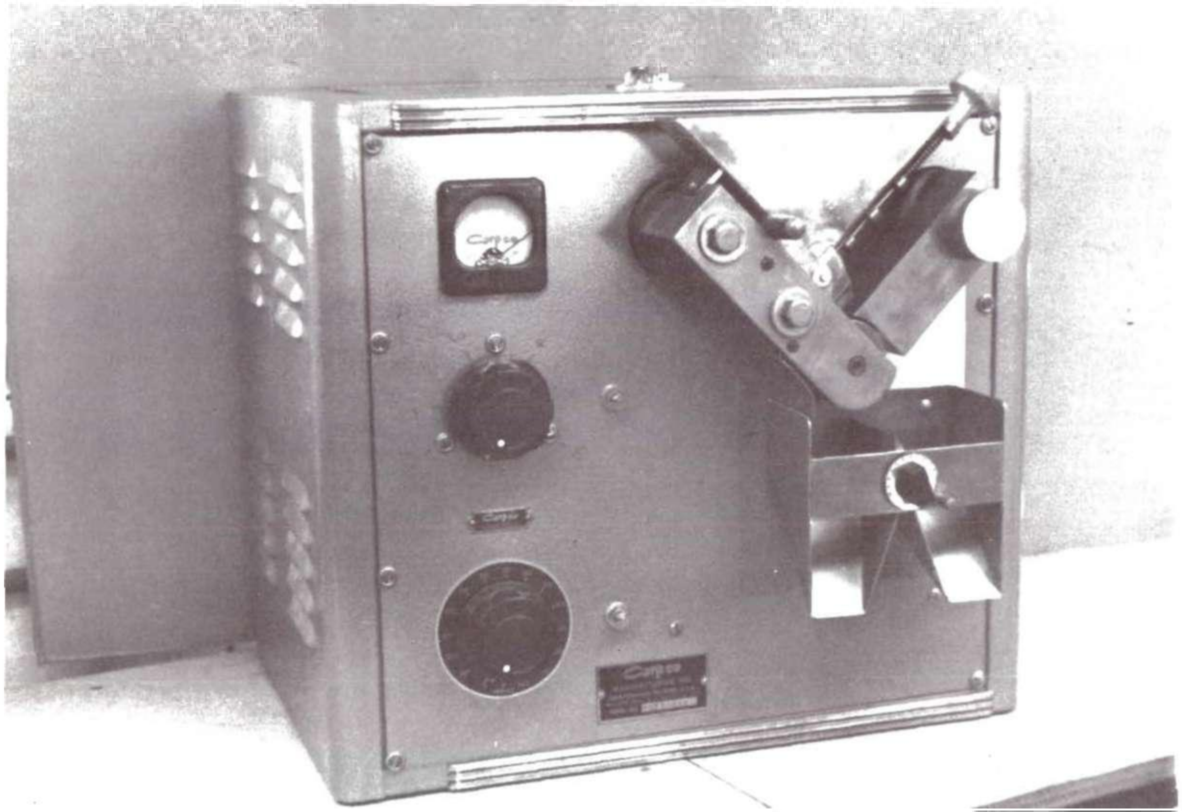

Figure 3. Photograph. The Carpco M-127 Magnetic Separator.

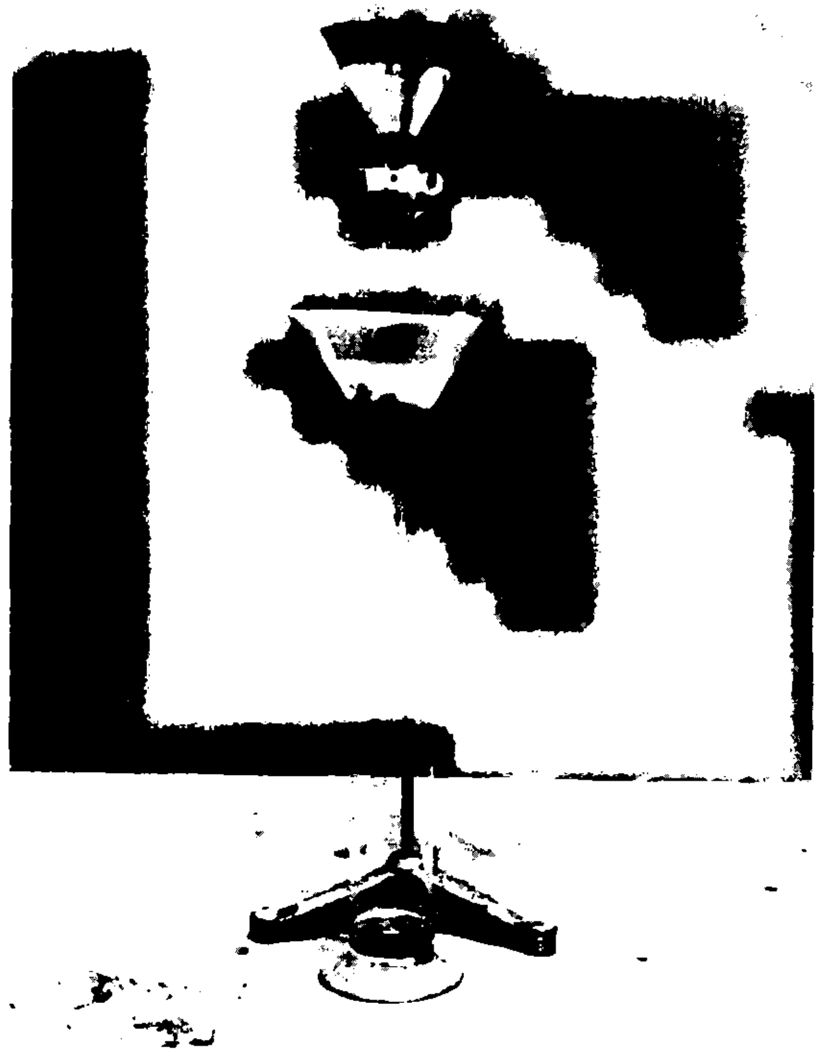

Figure 4. Photograph. Apparatus for Heavy Fluid Separation.

CHAPTER IV

PROCEDURE

Sampling

Nine separate soil samples were obtained from four proposed construction sites in the Atlanta area. These samples were supplied by the Law Engineering Testing Company from preliminary foundation investigations. The samples were secured in an undisturbed condition by the use of thin walled samplers with an area ratio of 11 per cent.

The sites selected consisted of residual soils with a high mica content in the intermediate and partially weathered zones. The sampling depths ranged from 2 to 15 feet and the penetration resistance varied from 6 to 20 blows per foot. All of the samples had the characteristic banded and folded appearance of saprolites (Figure 5), and several had bands consisting of almost 100 per cent mica (8).

Classification

The specific gravity, grain size curve, liquid limit and plastic limit of each sample was determined by standard laboratory procedure (10). The plastic limits are poorly defined because the mica particles tend to cause the soil to break into pieces before the actual plastic limit is reached.

The Unified Soil Classification System and the Bureau of Public Roads Classification System were both used to classify the soils. The

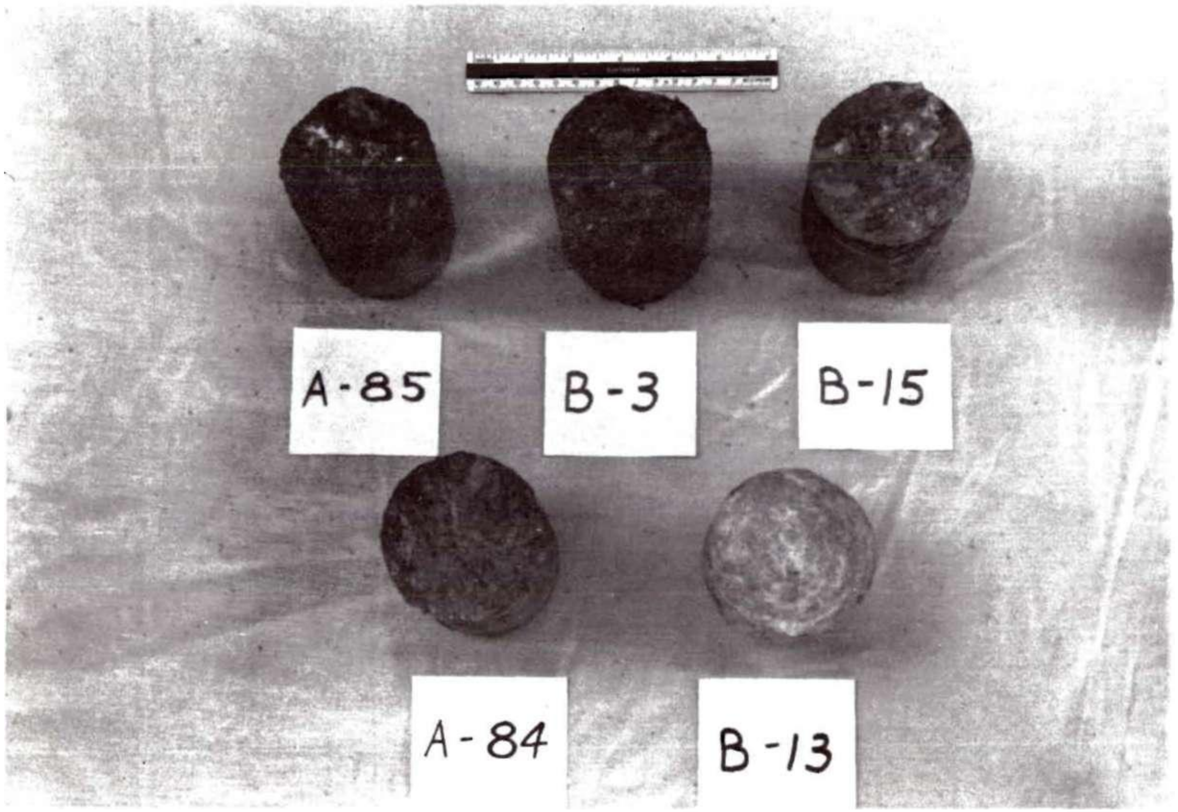

Figure 5. Photograph Saprolite Soil Samples Used in Tests

soil samples ranged from SM to SM-SW (Unified) and A-2-4 to A-2-7 (BPR) and the soil description for all the samples was a silty micaceous sand (Table 1).

Consolidation Tests

The testing program consisted of 12 separate consolidation tests conducted in three series. The first series of tests included four consolidation tests of soil samples No. 1 and No. 2 (see Table 1). Two samples were selected so as to compare the results of the consolidation tests. These samples were subjected to a maximum load of 16,000 psf. The second and third series were four consolidation tests each, conducted on samples No. 3-9. The samples were subjected to a maximum load of 32,000 psf and then unloaded in three increments to determine the rebound characteristics.

Sample Preparation and Testing

The undisturbed samples were removed from the Shelby tubes by hydraulic extrusion and trimmed to the size of the consolidometer rings. After placing the samples in the consolidometers, saturated cotton was placed around the ring and the consolidometer was encased in a plastic cover to insure constant moisture content. An initial load of 100 psf was applied to each sample for 24 hours prior to testing, to serve as a seating load. The loading schedule for the tests was as follows:

Table 1. Description and Classification of Materials

Sample Number	Description	Classification BPR	Unified
1.	Grey Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM
2.	Grey Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM
3.	Orange Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM
4.	Orange Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM
5.	Brownish-Yellow Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM
6.	Reddish-Brown Micaceous Silty Sand Containing Fine Mica	A-2-4	SM
7.	Reddish-Brown Micaceous Silty Sand Containing Fine Mica	A-2-7	SM
8.	Reddish-Brown Micaceous Silty Sand Containing Fine Mica	A-2-7	SM
9.	Reddish-Yellow Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-5	SM
10.	Reddish-Brown Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM-SW
11.	Reddish-Brown Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-5	SM
12.	Reddish-Brown Micaceous Silty Sand Containing Fine and Coarse Mica	A-2-4	SM

500 psf	16000 psf
1000	32000
2000	10000
4000	3000
8000	100

After each load was applied, the micrometer dial gauge was read at the following elapsed times: 15 seconds, 30 seconds, 1 minute, 2 minutes, 4 minutes, 8 minutes, 16 minutes, 32 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 10 hours, and 24 hours. The micrometer dial gauge was read at 24 hour intervals thereafter until 100 per cent consolidation under each load was achieved (10). After the consolidation tests were completed, each sample was removed from the consolidometer and the mica content determined.

Mica Content

The primary problem encountered in performing this research was developing an accurate and rapid means of determining the mica content of the soil samples. After many trials with variable success (see "Discussion," Chapter V), a procedure was adopted which is outlined below.

Sieve Analysis. After removal from the consolidometer, each sample was dried in an oven at 105 C^{o} for 24 hours. The average weight of the samples after drying was 200 grams. The soil was then separated into size fractions by means of a mechanical sieving device. The fraction sizes were: No. 10 (2.00 mm), No. 20 (0.840 mm), No. 40 (0.420 mm), No. 60 (0.250 mm), No. 100 (0.125 mm), No. 200 (0.074 mm), and the portion finer than 0.074 mm. Each of these sieve sizes was examined under a microscope to determine the particle shape and to get some idea of the approximate mica content of each sieve size.

Magnetic Separation. The main minerals composing the samples tested are enumerated in Table 2, along with their average specific gravities and magnetic properties. By the use of a high intensity magnetic field, the slightly magnetic property of the mica can be used to advantage in separating the non-magnetic minerals from the slightly magnetic portion.

For this study, a Carpco M-127 high intensity magnetic separator from the Minerals Laboratory at the Georgia Institute of Technology was used. Each sieve size, except the fraction finer than 0.074 mm (No. 200 sieve) was introduced into the magnetic separator and passed through the field a sufficient number of times to separate the magnetic and non-magnetic portions of the soil. The number of passes required varied with the particle size, the finer particles requiring a greater number of passes. The average time required to separate all the sieve sizes (excluding the material finer than the No. 200 sieve) was about one hour. The fraction smaller than the No. 200 sieve was so fine that the proper flow rate could not be established through the separator and a satisfactory separation could not be obtained. After separation a representative sample from each sieve size was examined under the microscope to determine the efficiency of the process.

Table 2. Typical Mineralogical Composition and Index Properties

Mineral	Specific Gravity	Magnetic Property
Quartz	2.65	Non-Magnetic
Kaolonite	2.60 - 2.63	Non-Magnetic
Mica (Biotite)	2.70 - 3.10	Weakly Magnetic
Mica (Muscovite)	2.80 - 2.88	Weakly Magnetic
Mica (Vermiculite)	2.20 - 2.70	Weakly Magnetic
Gibbsite	2.29 - 2.42	Non-Magnetic
Feldspar	2.54 - 2.56	Non-Magnetic
Halloysite	2.10 - 2.30	Non-Magnetic

Heavy Fluid Separation. The specific gravity of mica is considerably higher than that of the other minerals present in the soil samples (Table 2). The heavy fluid separation is based on this difference in specific gravities. To achieve separation, a fluid with a specific gravity of 2.66 was obtained.

The average percentage of each fluid used to obtain the correct specific gravity was: 78 per cent of tetrabromoethane and 22 per cent of tetracholoroethane. The specific gravity of the fluid for each test was determined by using a pycnometer and analytical balances according to ASTM Procedure D854-50T. Caution should be used when working with these fluids since both are highly toxic (12). It is recommended that an adequate ventilating system such as an overhead ventilating hood be used during the testing.

Tetrachloroethane was used as a diluent rather than acetone, which is recommended by several references (12,13) because the tetrachloroethane is much less volatile than the acetone and the mixture will remain at a constant specific gravity for a longer period of time.

After obtaining the correct specific gravity, about 250 ml of the fluid was placed in the funnel (Figure 4) and the soil sample sprinkled over the surface of the fluid. A watch-glass was placed over the top of the funnel to prevent evaporation and the sample was allowed to set for about an hour to obtain separation. After settling, the valve on the funnel stem was opened allowing the mica particles to be drained off and collected on the filter paper below the funnel. The mica particles were washed in acetone and then in water. Each sample was dried, weighed and again examined under a microscope to assess the completeness of the separation.

Petrographic Microscope

The mica content of the soil portion finer than 0.074 mm (No. 200 Sieve) was found by a statistical method using a petrographic microscope. Before placing a sample of soil under the microscope, the net-grating was calibrated by means of the stage micrometer scale. Each of the squares of the net-grating was 0.11 mm wide. A representative portion of each sample was placed on a glass slide and suspended in clear oil. A watch-glass was placed over the sample to spread the sample over the slide. The slide was then placed under the microscope and adjusted so that the greatest density of the sample was in the field of the net-grating of the micrometer disc.

The mica particles were distinguished from the other particles of the soil by first examining the sample under ordinary light and then by using the polarizing prisms and examining the sample under plane-polarized light.

Three separate representative samples were taken from each soil specimen and examined under the microscope, and a count was made on three different areas of each slide, making a total of nine counts from each soil specimen. The mica content was statistically computed from the counts made on each soil sample.

CHAPTER V

DISCUSSION OF RESULTS

Determination of Mica Content

A major portion of the time spent in this study was devoted to the problem of finding a means of determining the mica content of soil. (The results of the mica separation are enumerated in Table 3.) There are many methods outlined in the geological literature (12,13) which may be used to advantage to separate mica from rock; however, these methods often require extensive and specialized equipment and can be time-consuming, such as the microscopic analysis of a soil sample. The author endeavored to find a method that would be simple, quick and reasonably accurate. After trying many different approaches to the problem, the conclusion was reached that the only solution was to combine several methods into a procedure that would produce accurate results.

The problem of using only one method of separation is that, since soil is composed of so many different constituents and grain sizes, no one complete method of separation is effective on all the minerals present in the soil and on all the different grain sizes.

The portion of soil which was the most difficult to separate was the clay size (finer than 0.074 mm). The sand and silt size particles were rapidly and accurately (within 5 per cent) separated by means of a combination of magnetic separation and heavy fluid flotation; however, the particles in the clay range could not be separated by either of these means. The particles were so fine that a proper flow rate through the magnetic separator could not be obtained for an efficient separation. The heavy fluid process would not work on the fine portion because the particles were so fine that they could not be mixed intimately enough with the fluid to achieve separation. Several methods were employed to mix the fine portion of the soil: a vacuum was applied to the fluid and the soil to reduce the surface tension and produce mixing, a high speed centrifuge was used, and the fluid and soil were thoroughly stirred to produce a mixture; however, none of these methods worked satisfactorily. The method resorted to in analyzing the fine portion of soil was a statistical approximation of the mica percentage. Random samples of each soil were examined under the microscope and an average percentage of mica by volume was determined. The percentage of mica by weight was then computed by using the specific gravities of the soil and mica.

It may be argued that the mica present in the fine portion of the soil is more similar to a clay mineral than a mica mineral because of the weathering processes the particles have undergone. When subjected to weathering, the mica mineral is changed into a clay. Since the fine particles of soil have been extensively weathered, the mica particles may actually be in the transitional stage between mica and clay. The mica content of this fine portion of the soil would not then be as critical as the larger grain sizes, inasmuch as these large mica particles have not been chemically broken down by the processes of weathering.

The method used in this study to separate mica from soil samples was suitable to the purposes of this thesis; however, for a standard laboratory procedure there needs to be more refinement and more study of the problem of mica separation of soil.

Consolidation Tests

The pressure-void ratio curves for the consolidation tests, plotted on semi-logarithmic coordinates, are shown on Figures 10-21. The usual shape of the pressure-void ratio curve for an undisturbed normally consolidated clay is a flat curve at low pressures, a rapidly curving section at median pressures, and a steeper straight-line section at higher pressures. The straight-line section at higher pressures is termed the virgin compressibility curve.

The pressure-void ratio curves of the consolidation tests differed from the usual shape of the curve for undisturbed clays. The difference is that the curves for the samples containing a high percentage of mica did not have a straight line section, but were curved throughout the entire range of applied pressure. The virgin compressibility curve may become a straight line at higher pressures than were applied in these tests; however, for pressures up to 32,000 psf there is no straight line portion. The reason for the curved shape of the virgin compressibility curve is probably due to an arching or bridging of the voids in the soil by the mica particles. As the pressures on the soil are increased, the mica particles are broken and these voids collapse causing a greater reduction in the void ratio than occurs in normally consolidated clays.

The curved shape of the pressure-void ratio curves makes the determination of a preconsolidation load (P_c-Table 3) approximate at best. However, all the soils tested indicated that they have been preconsolidated. The preconsolidation loads were quite variable even for samples taken at the same sites and at the same depths (Nos. 1 and 4, 2 and 5). The lack of correlation between the preconsolidation loads is due partially to the error associated with estimating P_c from the pressure-void ratio curves. However, the primary cause is probably the variation in the residual stresses due to cooling and distortion of the parent material, and the stresses due to differential weathering of the minerals in the soil.

To compare the effect of the mica content on the compressibility of the samples, the compression index, which is a measure of the relative compressibility of a soil at high pressures, was determined for each test (Table 3). The compression index is a measure of the slope of the virgin portion of the compression curve: the higher the compression index, the greater the compressibility of the soil. Since the basic assumption in defining the compression index is that of a straight line virgin curve on the e-logP plot, the values obtained for the samples containing a high percentage of mica are approximate because the curves do not become straight lines.

The mica content, by weight, of the samples is plotted versus the compression index in Figure 6. The mica content by weight is essentially the same as the grain shape factor F_s as defined by Terzaghi (7). Also on the same figure the equation given by Tate

Table 3. Summary of Results

Sample Number	Percentage of Mica by Weight	Initial Void Ratio e_o	Degree of Saturation %	Coefficient of Volume Compressibility m_v for 4000 lbs/ft^2 (in^2/lb)
1.	37.0	1.19	77.3	1.35 . 10^{-5}
2	37.9	1.18	79.3	1.35 . 10^{-5}
3	32.0	0.96	91.4	1.05 . 10^{-5}
4	32.2	1.11	77.0	1.09 . 10^{-5}
5	39.7	1.23	87.9	2.05 . 10^{-5}
6	31.9	0.65	52.5	0.60 . 10^{-5}
7	9.0	0.98	62.8	2.27 . 10^{-5}
8	8.0	0.74	87.0	0.80 . 10^{-5}
9	35.0	1.28	59.2	1.24 . 10^{-5}
10	38.1	0.94	72.3	0.85 . 10^{-5}
11	31.0	0.96	86.2	0.60 . 10^{-5}
12	39.1	0.92	87.0	0.67 . 10^{-5}

Table 3. Summary of Results
(Continued)

Sample Number	Percentage of Mica by Weight	Compression Index Cc	Coefficient of Consolidation Cv (in^2/min)
1	37.0	0.412	$1.31 \cdot 10^{-3}$
2	37.9	0.435	$0.189 \cdot 10^{-3}$
3	32.0	0.319	$1.97 \cdot 10^{-3}$
4	32.2	0.329	$1.85 \cdot 10^{-3}$
5	39.7	0.414	$0.40 \cdot 10^{-3}$
6	31.9	0.156	$2.06 \cdot 10^{-3}$
7	9.0	0.306	$1.05 \cdot 10^{-3}$
8	8.0	0.216	$1.20 \cdot 10^{-3}$
9	35.0	0.542	$0.61 \cdot 10^{-3}$
10	38.1	0.342	$1.08 \cdot 10^{-3}$
11	31.0	0.296	$1.09 \cdot 10^{-3}$
12	39.1	0.355	$1.68 \cdot 10^{-3}$

Table 3. Summary of Results
(Continued)

Sample Number	Percentage of Mica by Weight	Preconsolidation Load Pc (lbs/ft^2)	Coefficient Secondary Consolidation (min^{-1})
1	37.0	5100	$1.14 \cdot 10^{-2}$
2	37.9	4900	$0.685 \cdot 10^{-2}$
3	37.0	3900	$0.685 \cdot 10^{-2}$
4	32.2	3600	$0.685 \cdot 10^{-2}$
5	39.7	3100	$1.27 \cdot 10^{-2}$
6	31.9	5500	$0.806 \cdot 10^{-2}$
7	9.0	2000	$0.332 \cdot 10^{-2}$
8	8.0	5800	$0.332 \cdot 10^{-2}$
9	35.0	5100	$0.506 \cdot 10^{-2}$
10	38.1	2100	$0.806 \cdot 10^{-2}$
11	31.0	8800	$0.332 \cdot 10^{-2}$
12	39.1	7300	$1.03 \cdot 10^{-2}$

and Larew (3) for micaceous sands and silts compacted to maximum Proctor densities is plotted. This equation is:

$$c_c = .025 + 0.21M + .3M^2$$

where M is the mica content expressed as a fraction, and c_c is the compression index. There is considerable scatter of the points on the graph; however, there is an indication that there may be a series of curves of the same general shape as the one defined by Tate and Larew but at higher values of c_c for soils containing higher mica contents (Figure 6). All of the points plot above the curve given by Tate and Larew, which was expected since the curve is for soils which have been compacted to the maximum Proctor density. The reason for comparing the compression index and the mica content was to determine if an empirical relation between these two could be obtained. However, the effects of other factors besides the mica content were so significant that a definite relationship could not be established. The reason for the scatter of results can be seen from an examination of the initial void ratio and saturation of the samples listed in Table 3. As an example, for sample No. 6, the initial void ratio is 0.65 and the percent saturation is 52.5. The compression index for this sample is 0.156, which is the lowest value obtained and the mica content was 32.0%. By comparison, sample No. 9 has an initial void ratio of 1.28 and 59.2% saturation, and a compression index of 0.542 which was the highest value obtained in the tests. These two samples illustrate that

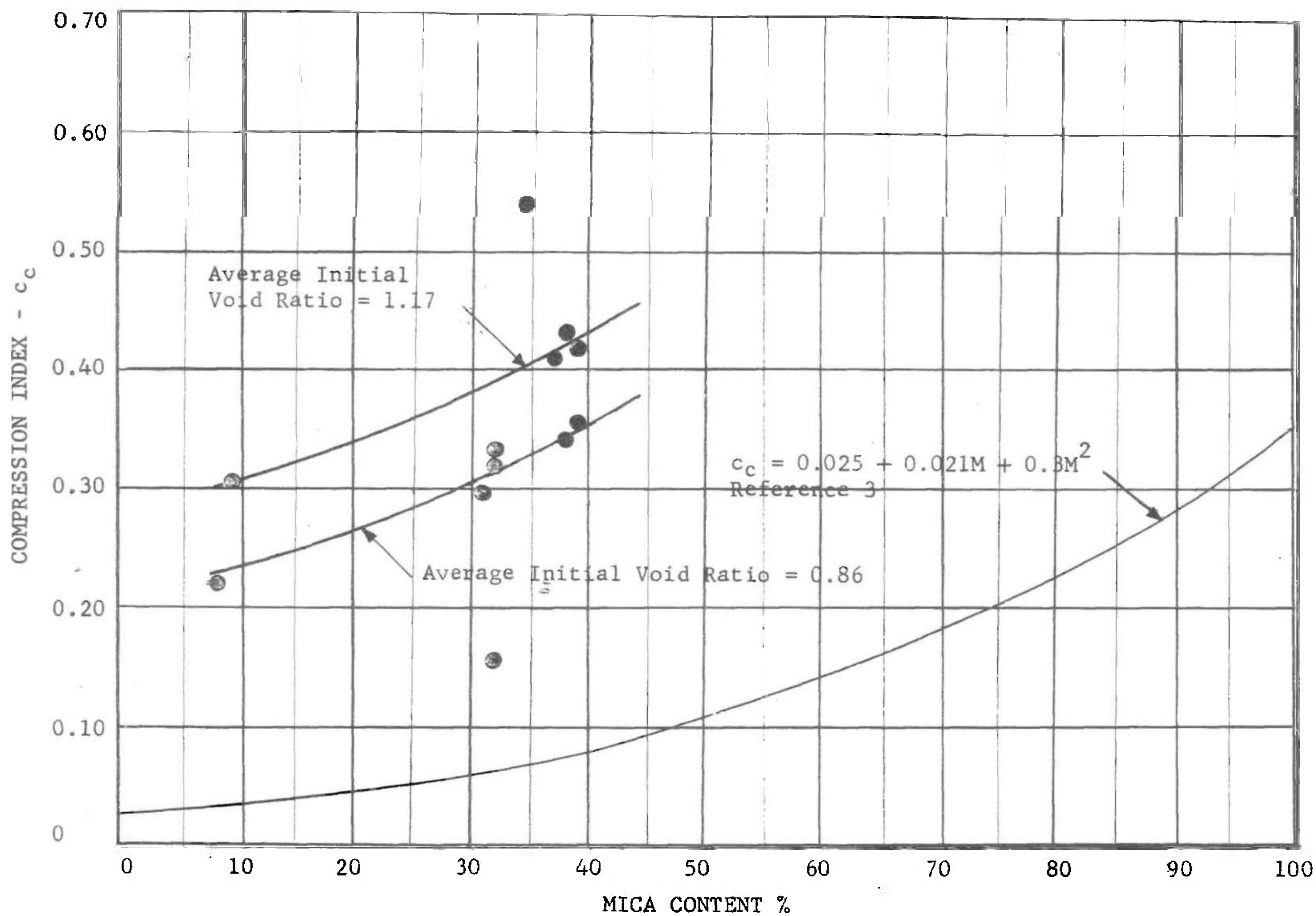

Figure 6. Mica Content Versus Compression Index - c_c

while it is true the mica content has an influence on the compressibility, it is not the only factor which has considerable influence on the compression characteristics of a soil.

Inasmuch as the compression index is approximate due to the curved shape of the virgin compressibility curve, the coefficient of volume compressibility (m_v) was computed for the samples at a load of 4000 psf/ft^2. The coefficient of volume compressibility represents the unit change of volume per unit of pressure, and is independent of the shape of the pressure-void ratio curve. A plot of the coefficient of volume compressibility versus mica content on Figure 7 indicates that m_v increases with increasing percentages of mica.

Decompression curves were determined for samples 5-12 and plotted on Figures 14-21. The elastic rebound was not as great as expected if it is assumed that the major portion of the compression of the samples is due to the elastic compression of the mica particles in the soil. However, the samples with the greater percentage of mica have a decompression curve that is definitely more curved than the samples with low mica content.

The relation between the void ratio and the compression index for undisturbed soils in the Southeastern United States has been expressed by Sowers (8) as:

$$c_c = 0.75\ (e - 0.55)$$

Figure 8 is a plot of this relation with the results of these tests plotted on the figure. All the points agree with this relation and

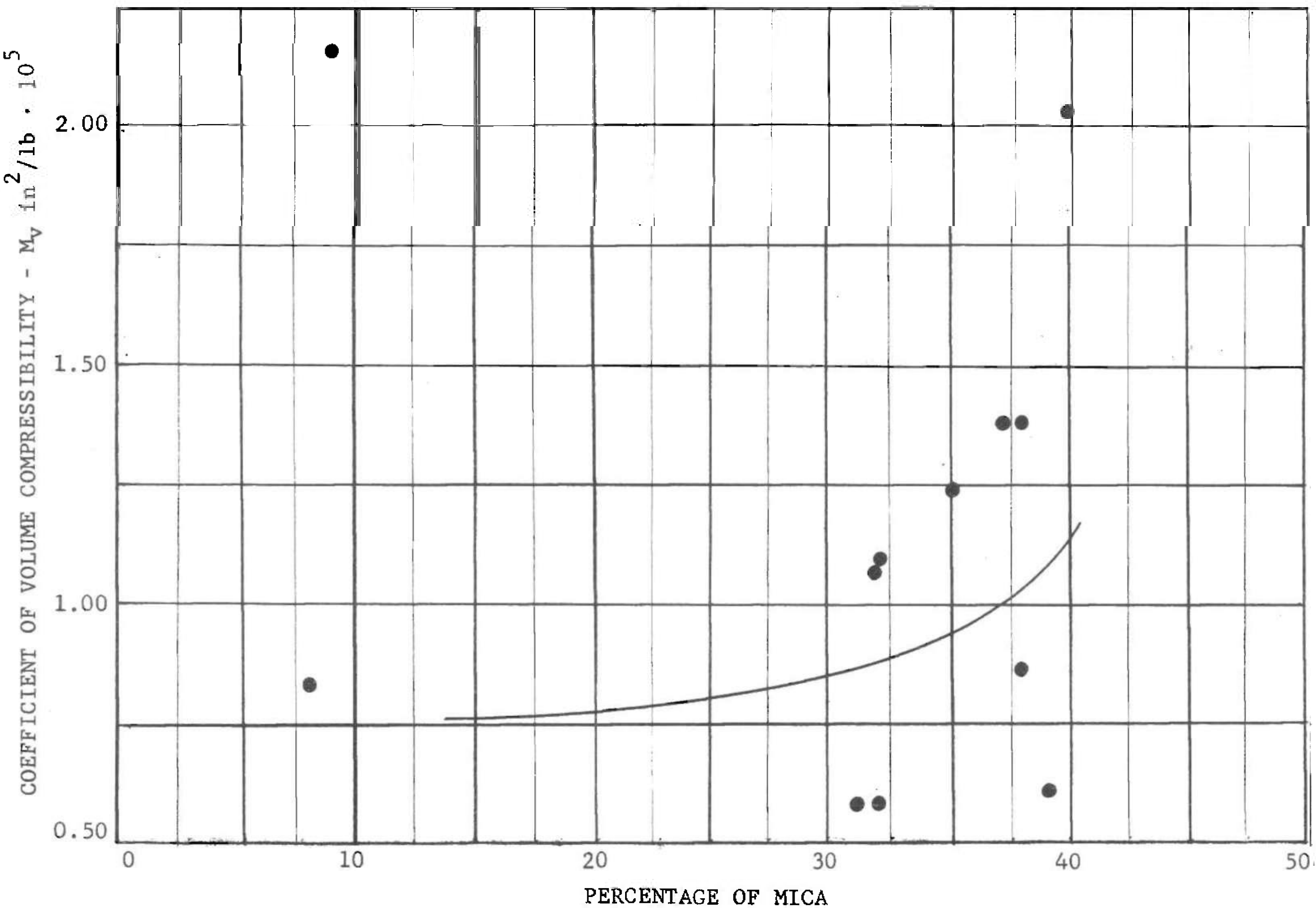

Figure 7. Mica Content Versus Coefficient of Volume Compressibility - M_v

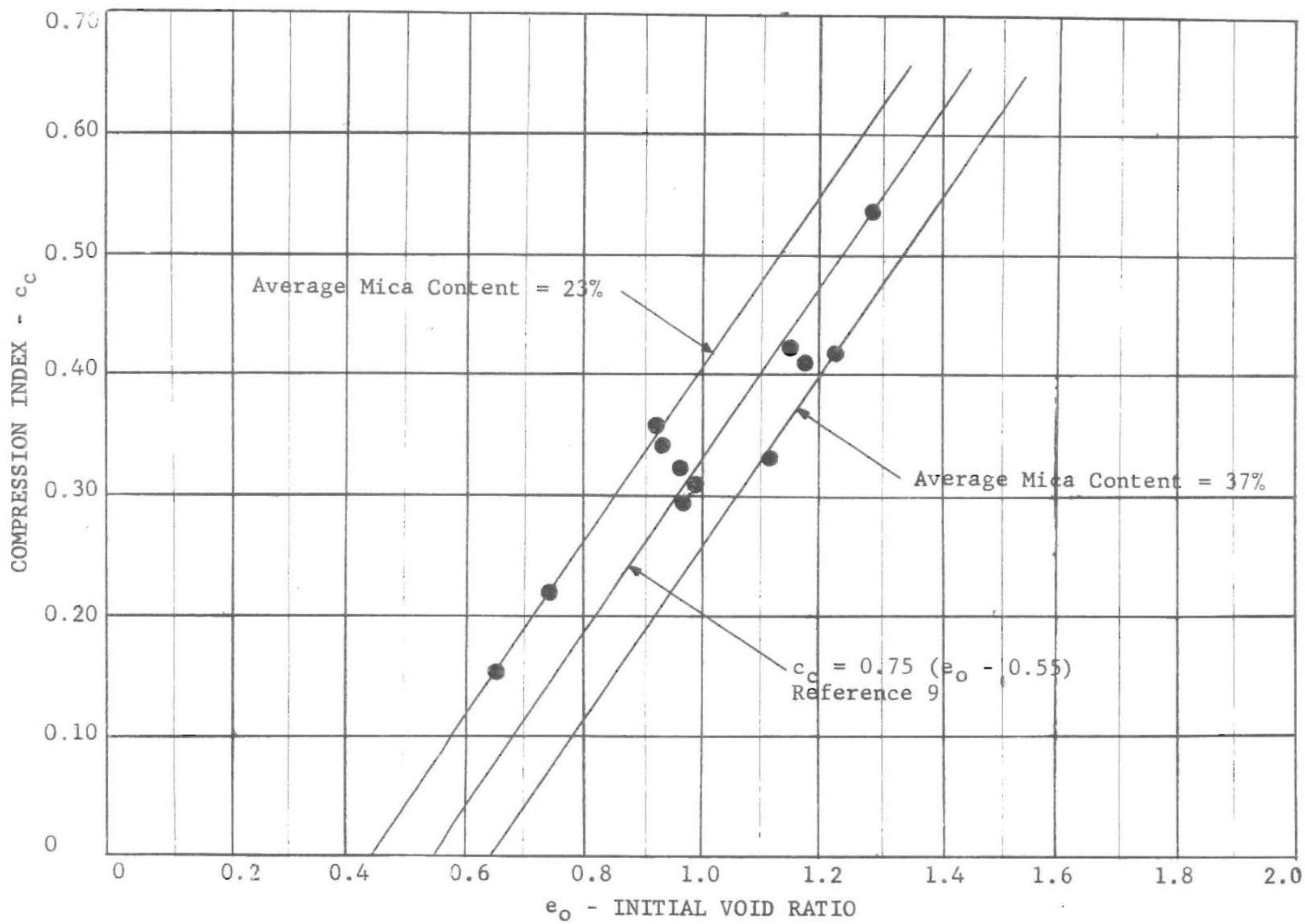

Figure 8. Compression Index - c_c Versus Initial Void Ratio - e_o

indicate that there is a family of curves for differing percentages of mica. The curve for high percentages of mica plots above the curve defined by Sowers. A comparison of the initial void ratio and the mica content showed considerable scatter and no definite relation could be obtained.

Time Settlement Curves

The initial or instantaneous consolidation of all the soil samples accounted for a major portion of the consolidation. As much as 85 per cent of the consolidation occurred instantaneously for the samples with a high mica content. The samples with lower mica contents had only 50 per cent of the consolidation occurring instantantaneously. The primary or hydrodynamic portion of the consolidation was rapid and 100 per cent consolidation was reached for all the samples in a relatively short period of time. This rapid consolidation occurred because the samples were not saturated. After reaching saturation the samples underwent primary consolidation in accordance with the Terzaghi theory, but the samples were all predominantly sandy and porous which resulted in rapid consolidation (Figures 22-33).

The coefficient of consolidation for each sample was computed for the load increment from 16,000 to 32,000 psf, and compared with the mica content of the samples. It was concluded that the coefficient of consolidation was generally greater for the samples with greater mica content.

Secondary Compression

Sufficient time for a complete study of the secondary consolidation of the samples was not available, but from the results there appears to be enough secondary consolidation occurring to make the study of this a worthwhile endeavor. Using the term α (15) which is defined as a coefficient which represents the rate of secondary compression, a plot of mica content versus the coefficient of secondary consolidation (Figure 9) indicates that the coefficient or the slope of the time-settlement curve increases with the increasing mica content. The scattering of points indicates that there are several other factors influencing the secondary consolidation in addition to the mica content.

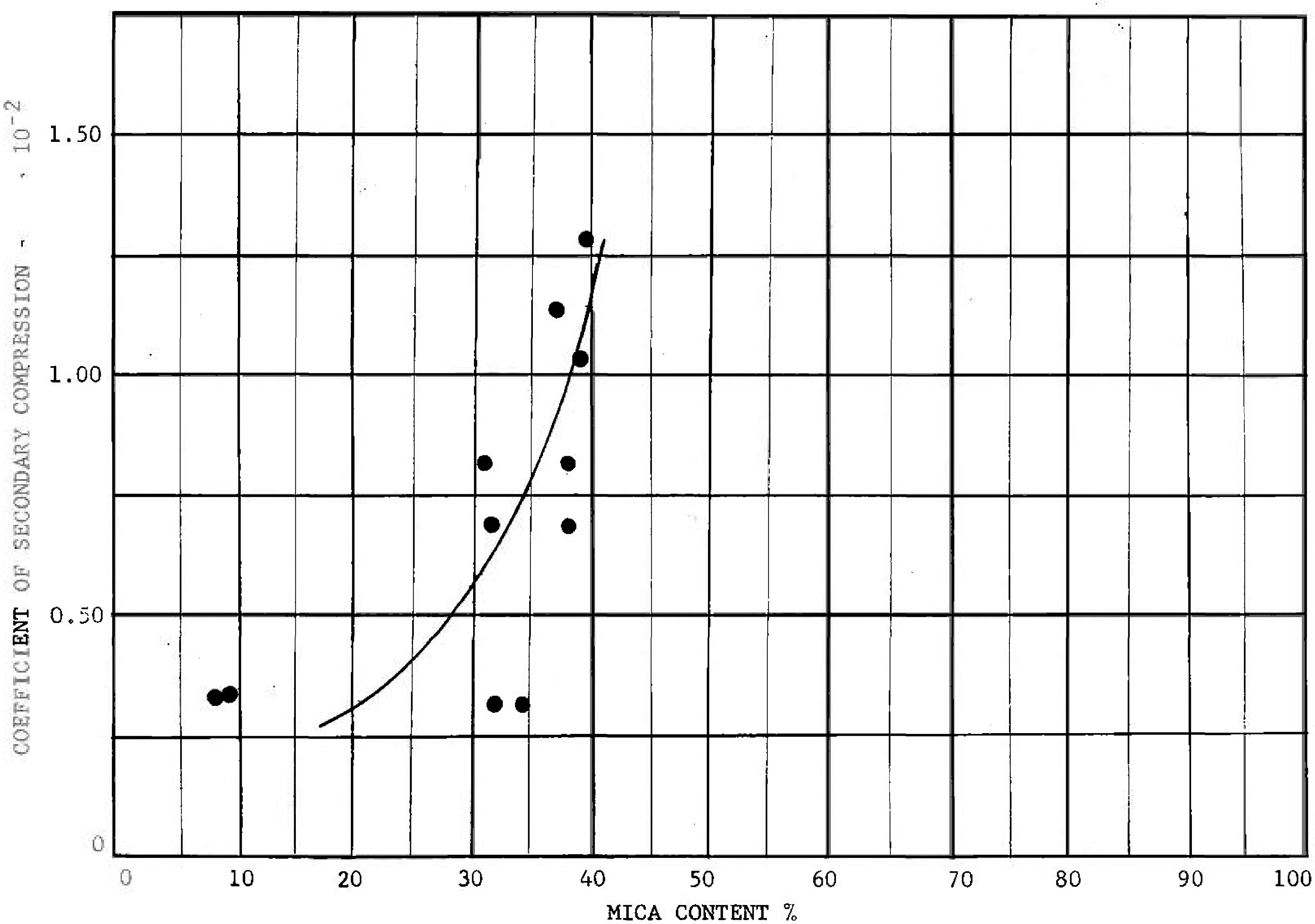

Figure 9. Mica Content Versus Coefficient of Secondary Compression - α

CHAPTER VI

CONCLUSIONS

1. The best procedure for the determination of mica content of a soil was found to be a combination of three methods, magnetic separation, heavy fluid flotation and microscopic analysis.

2. The pressure-void ratio curves for the soil samples containing a high percentage of mica failed to show a straight line virgin compressibility curve.

3. The compression index of a soil increases with increasing mica content, but a definite relation between the mica content and compression index was difficult to clearly define.

4. The preconsolidation loads were variable even for soil samples taken at the same site and same depth.

5. The initial or instantaneous compression of a soil increases with increasing mica content.

CHAPTER VII

RECOMMENDATIONS

1. Further research is needed to develop a standard laboratory procedure for the separation of mica from soil which would require a minimum of equipment and time.

2. Additional study of the elastic rebound of decompression curves of soils containing high mica contents should be undertaken to determine the influence of mica content.

3. A more complete study of the effect of mica content on the secondary compression of soils is recommended.

A P P E N D I X

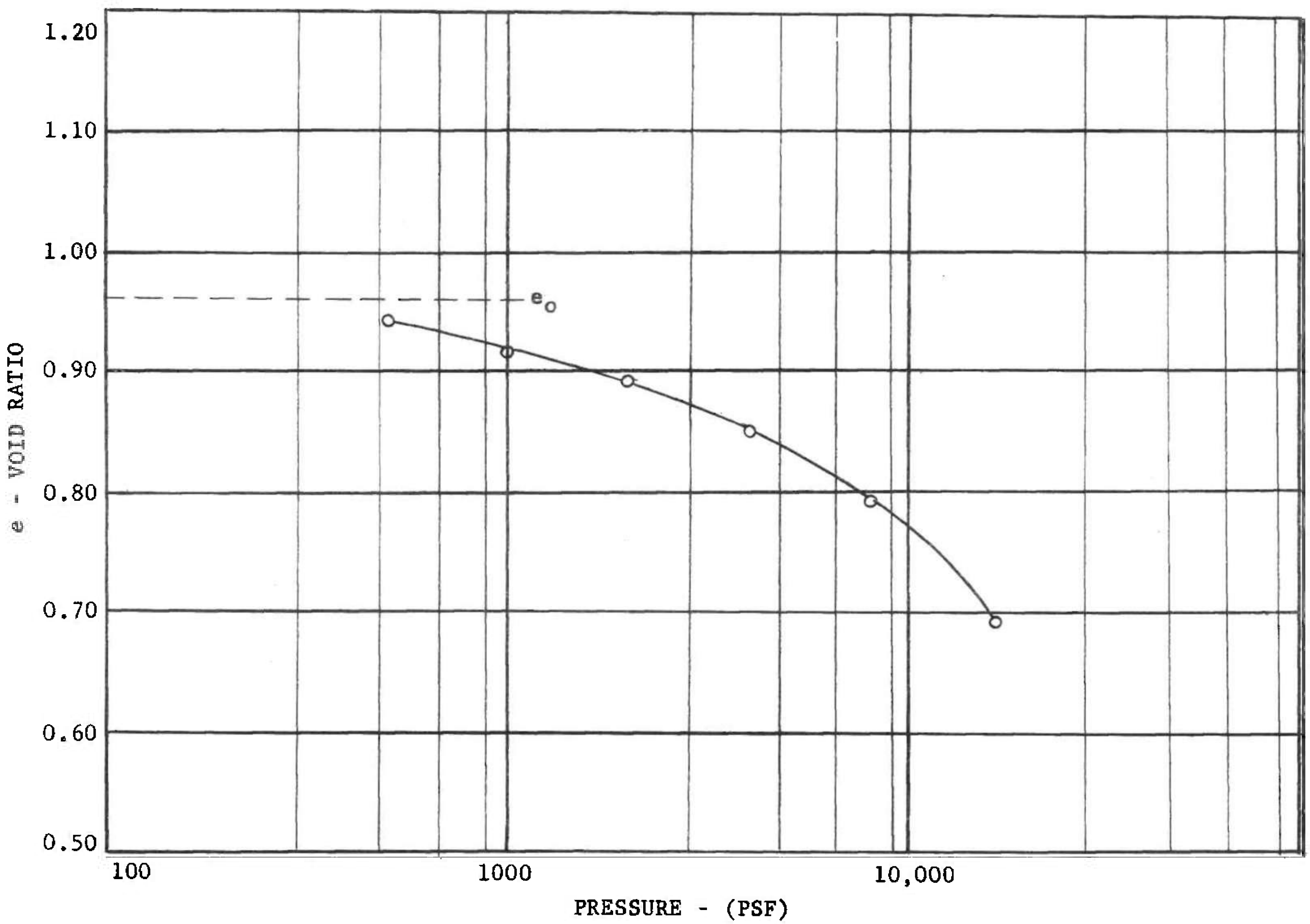

Figure 10. Pressure-Void Ratio Curve for Sample 1

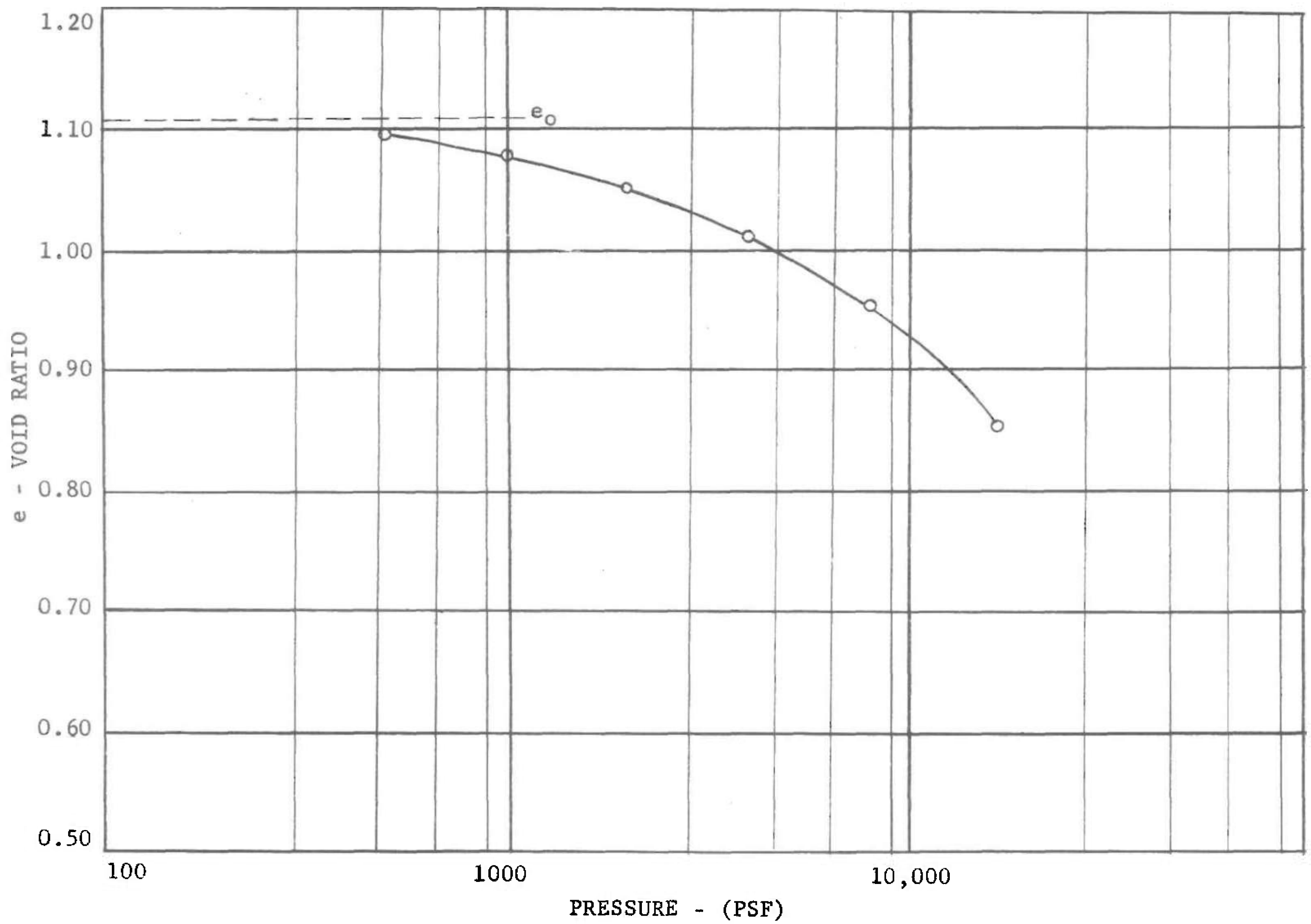

Figure 11. Pressure-Void Ratio Curve for Sample 2

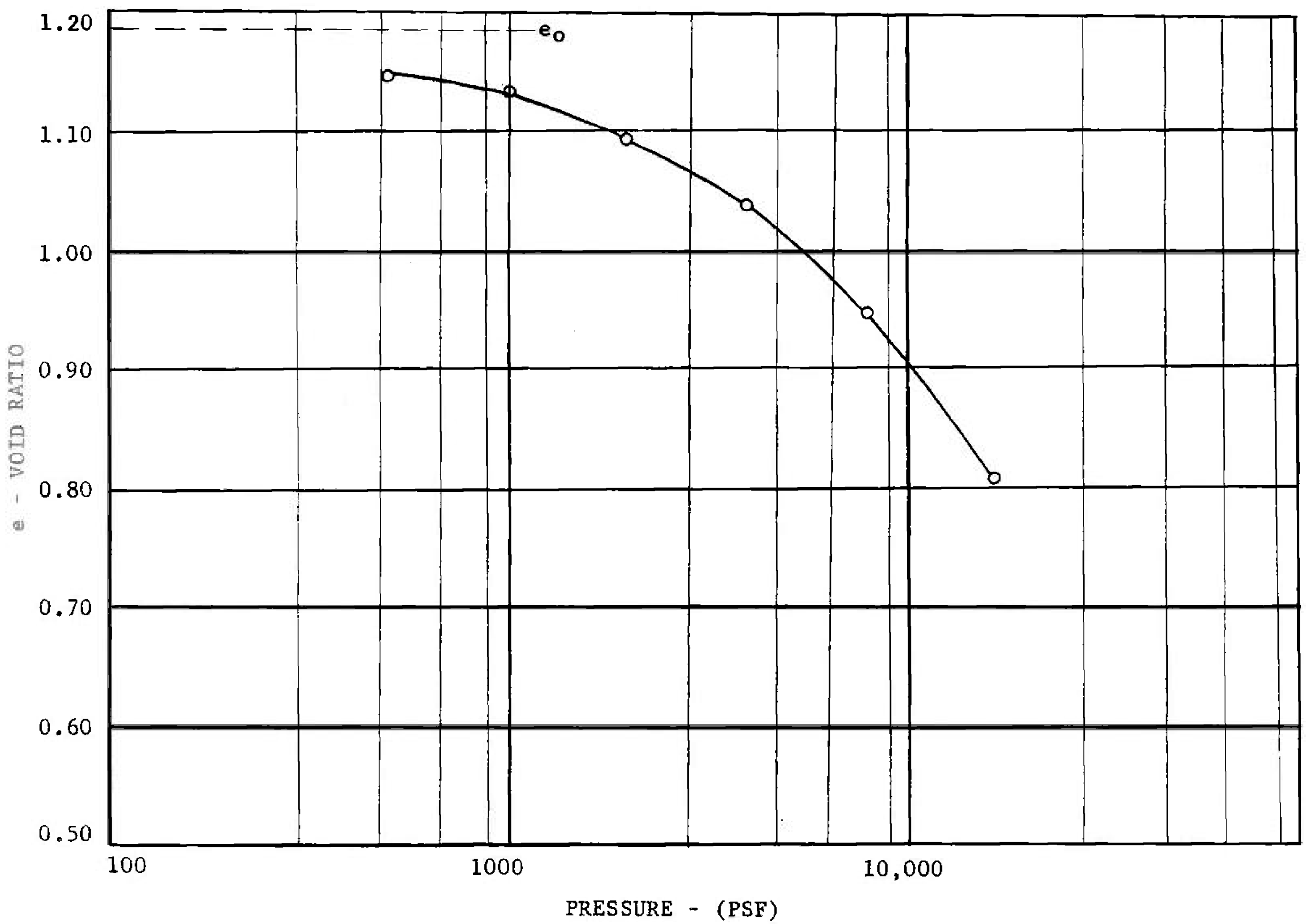

Figure 12. Pressure-Void Ratio Curve for Sample 3

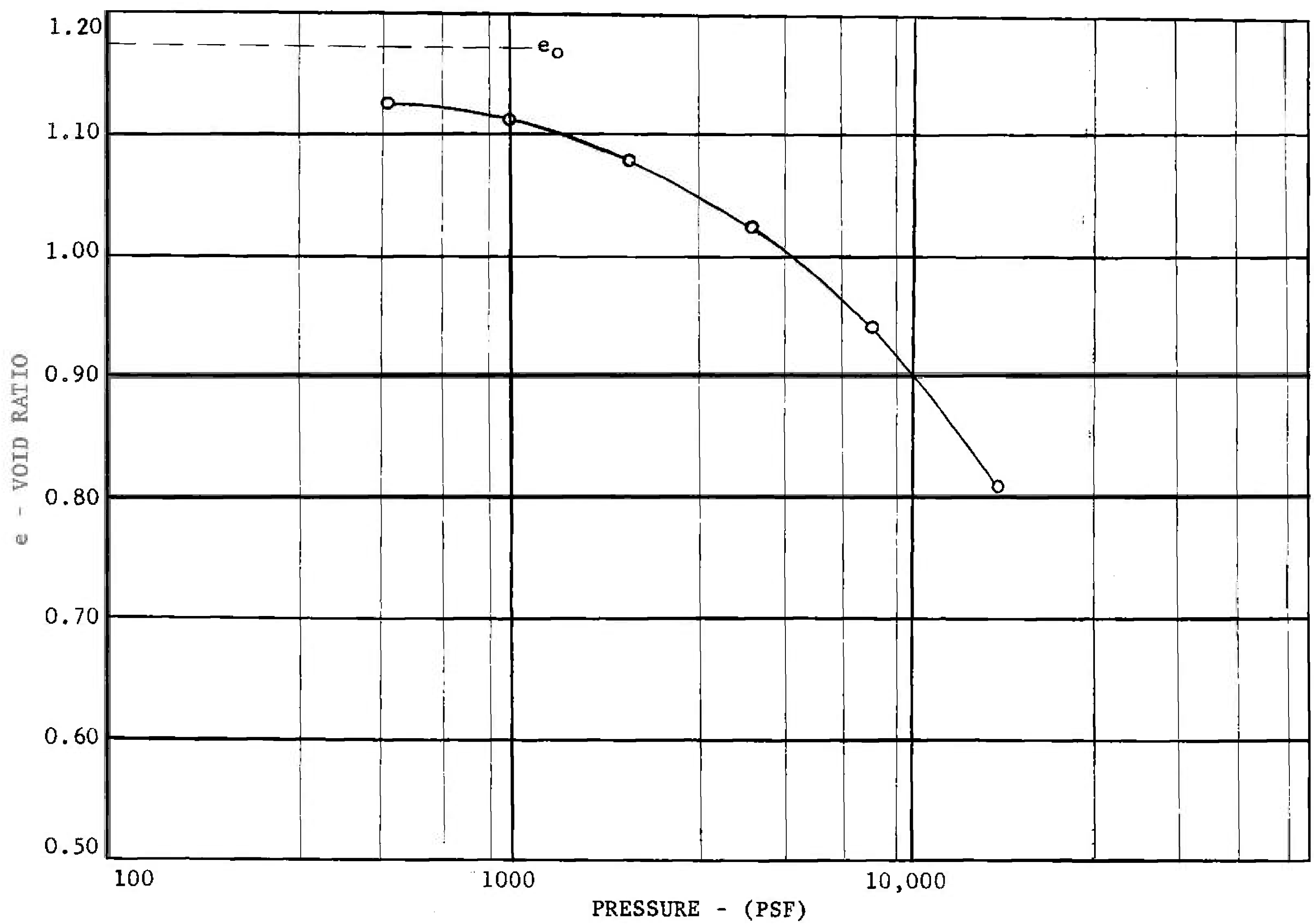

Figure 13. Pressure-Void Ratio Curve for Sample 4

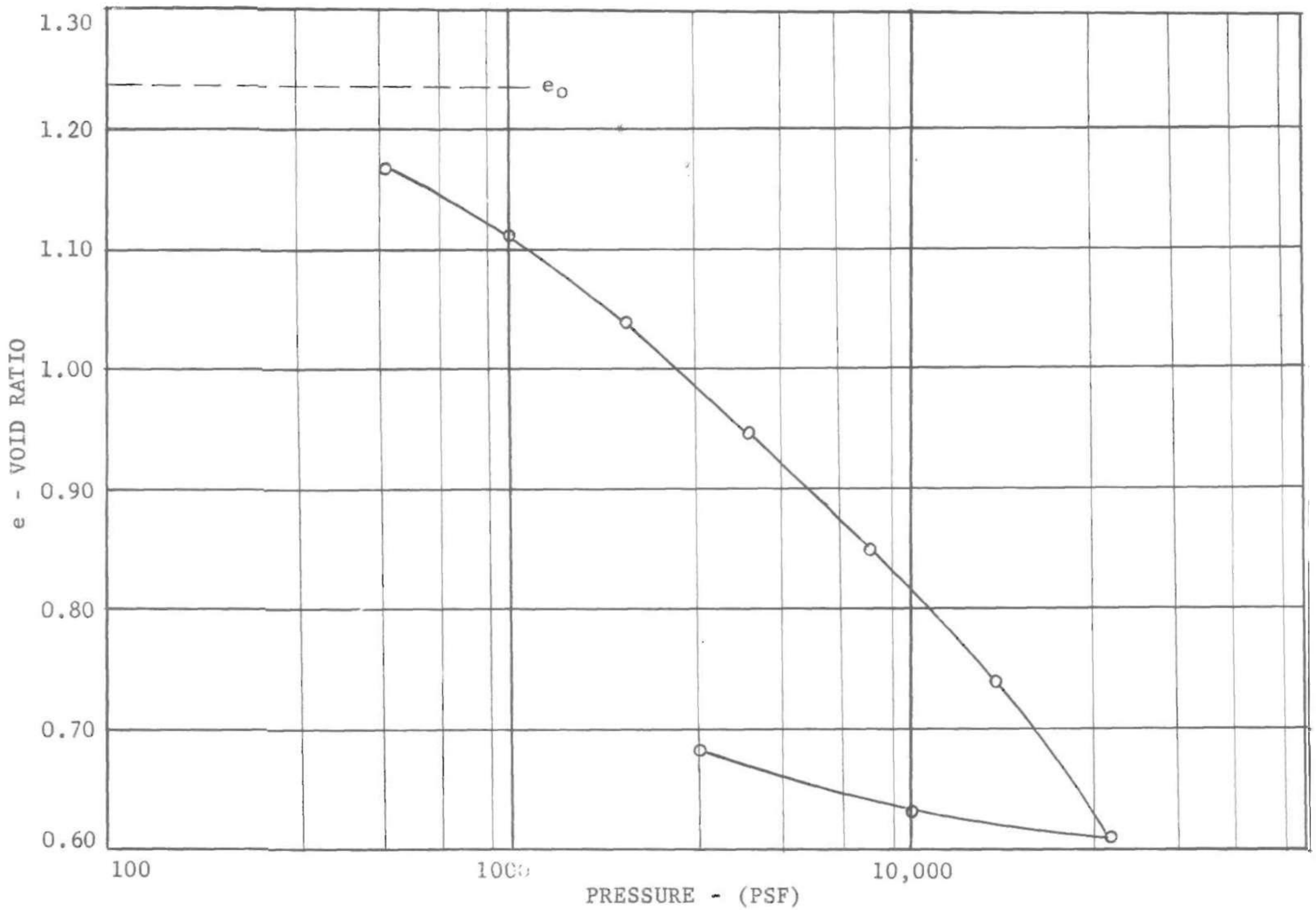

Figure 14. Pressure-Void Ratio Curve for Sample 5

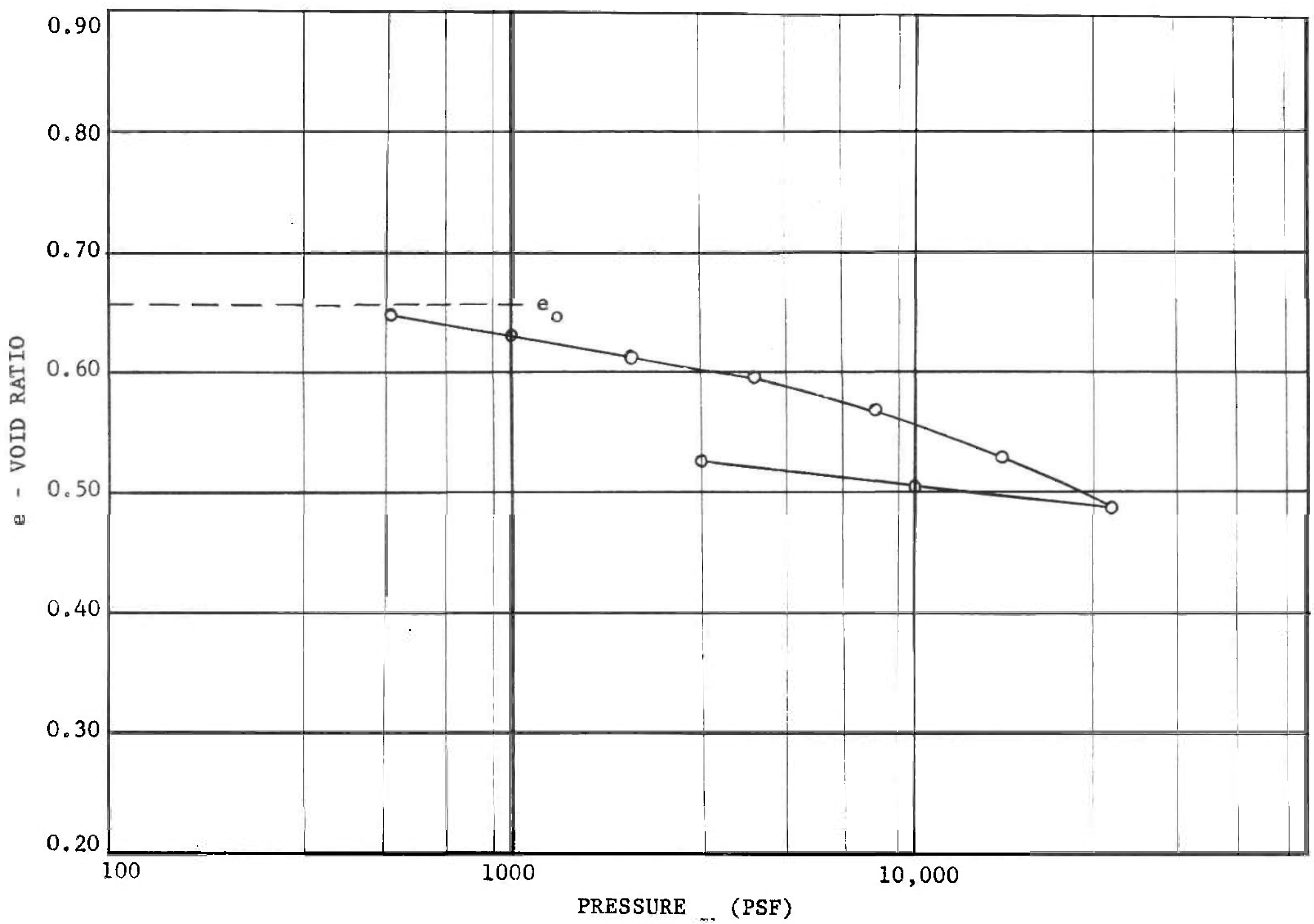

Figure 15. Pressure-Void Ratio Curve for Sample 6

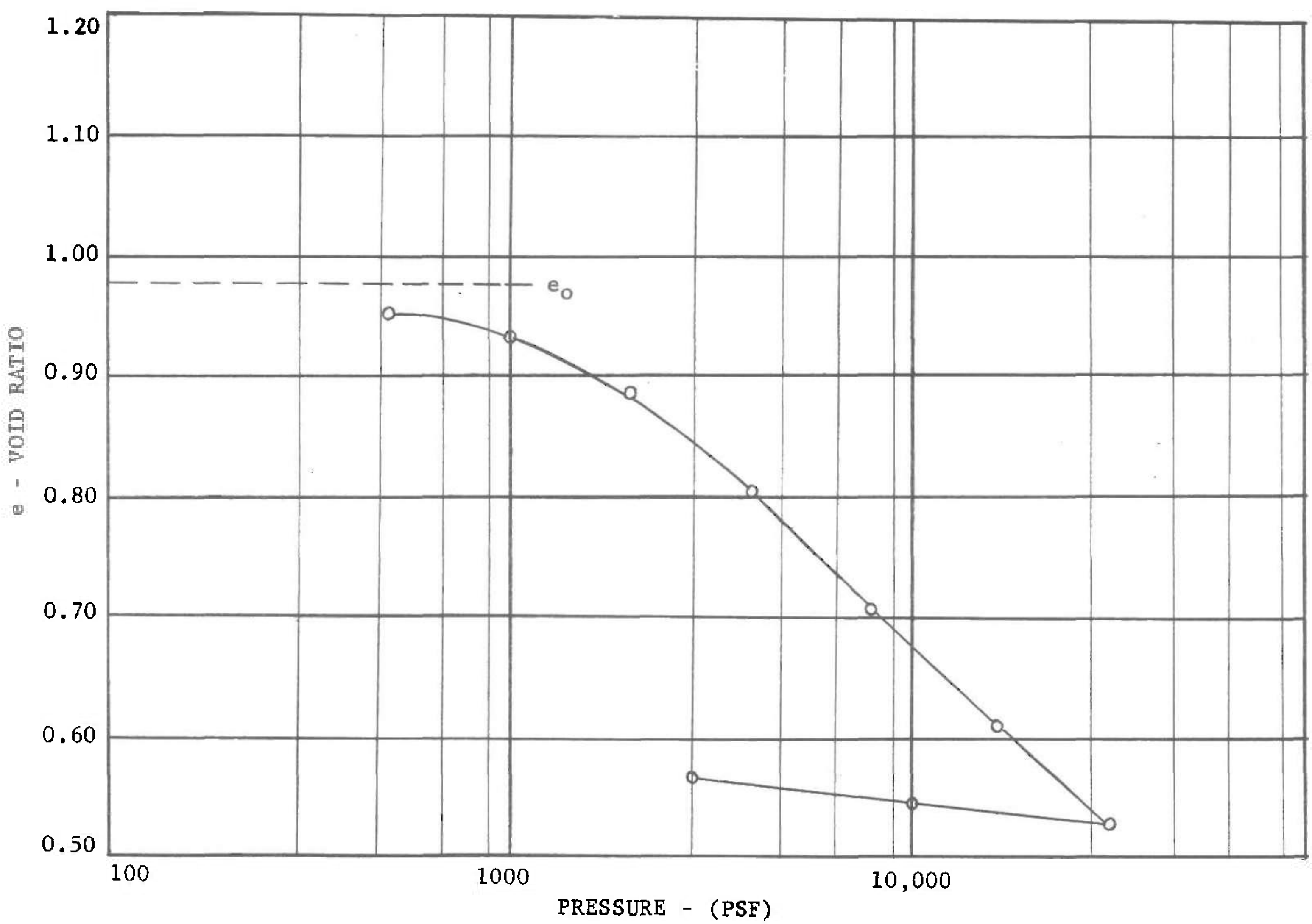

Figure 16. Pressure-Void Ratio Curve for Sample 7

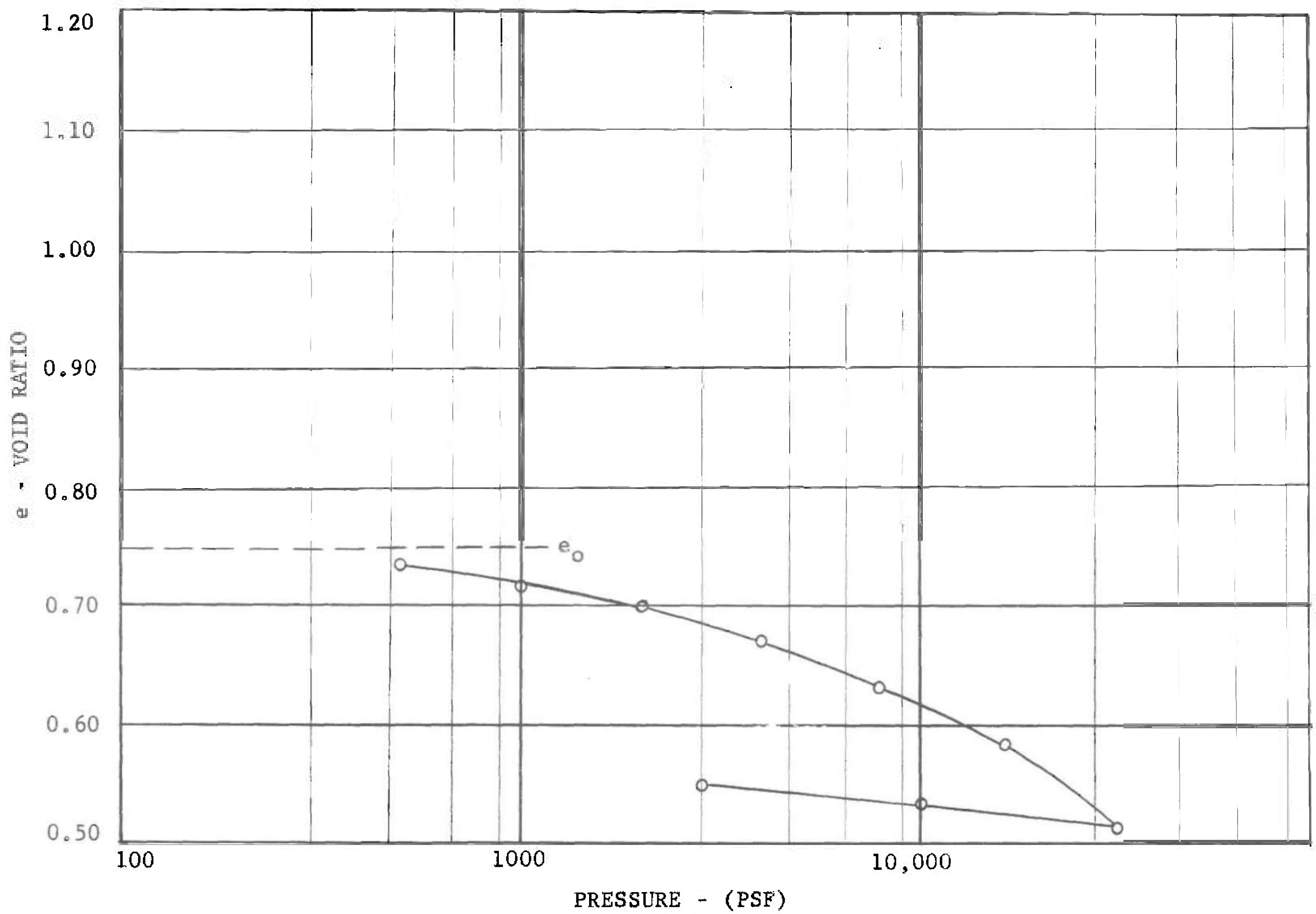

Figure 17. Pressure-Void Ratio Curve for Sample 8

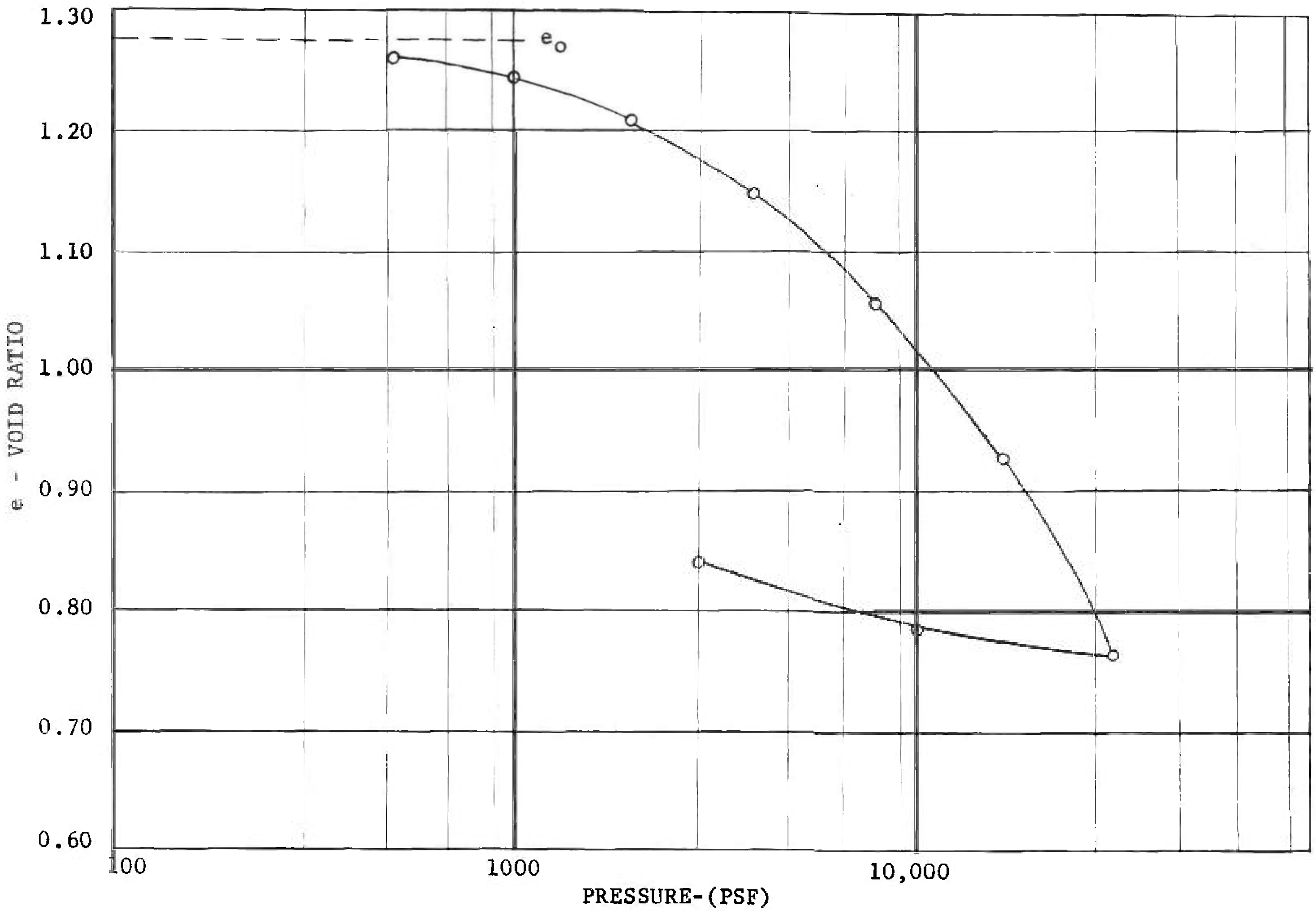

Figure 18. Pressure-Void Ratio Curve for Sample 9

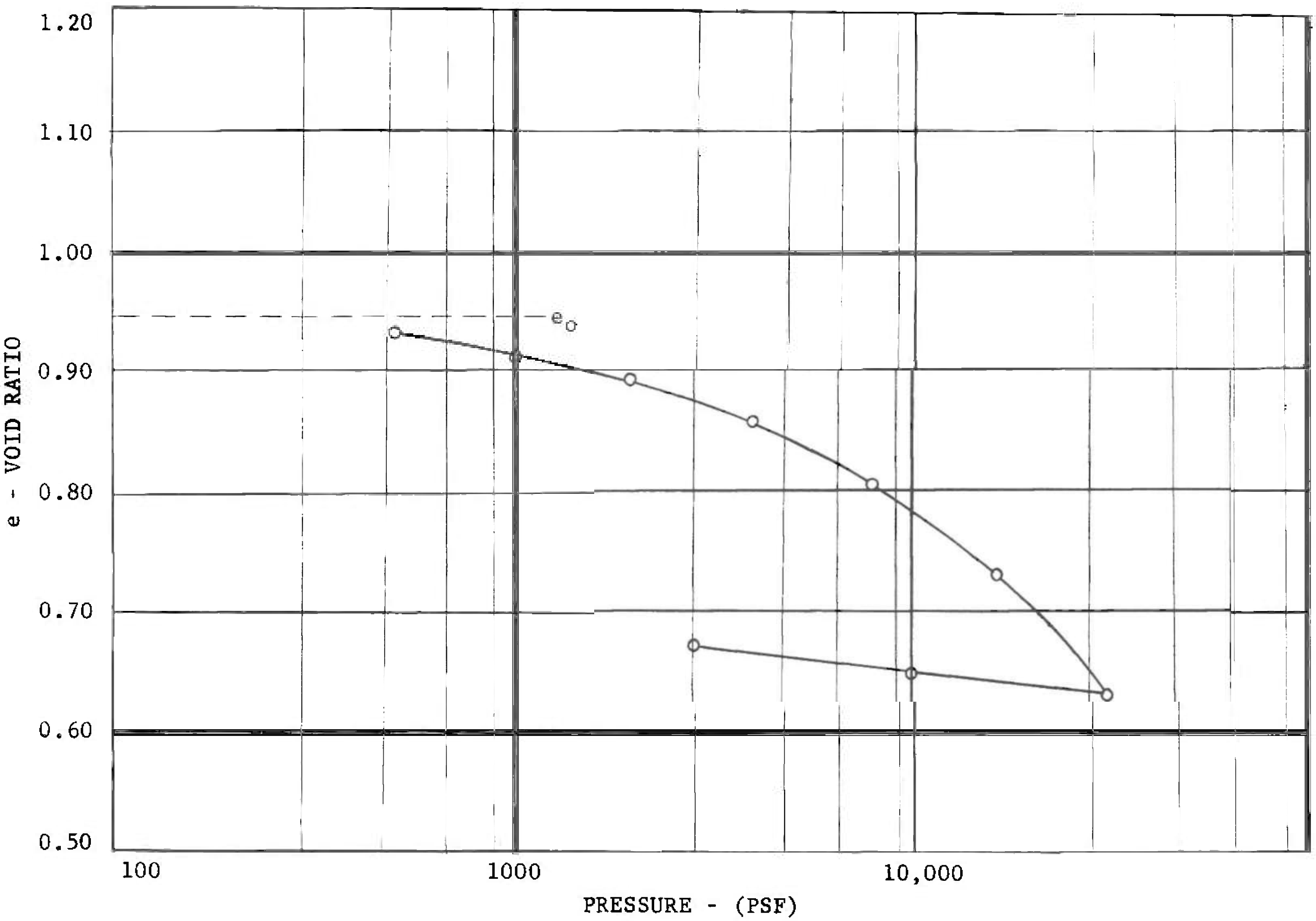

Figure 19. Pressure-Void Ratio Curve for Sample 10

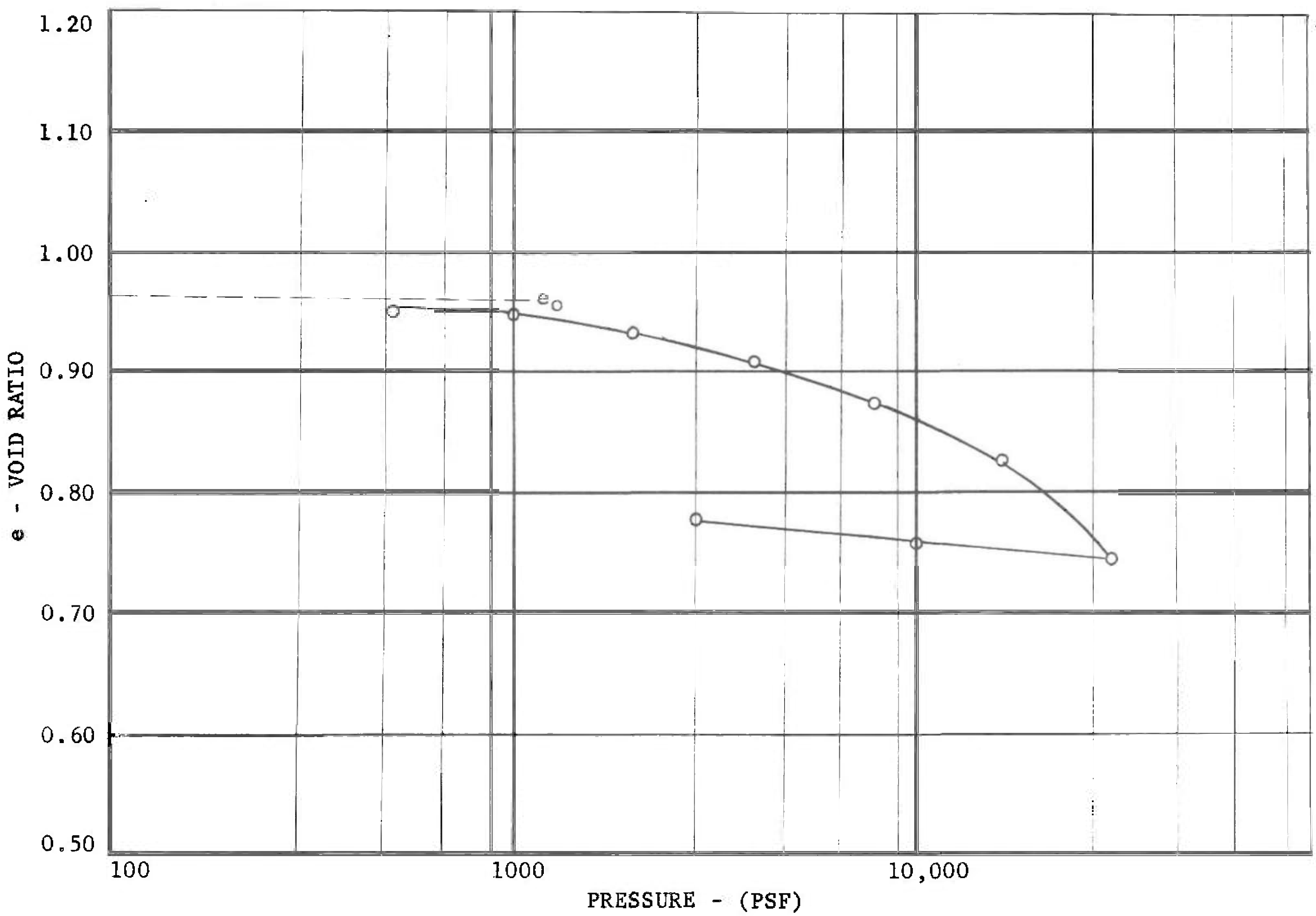

Figure 20. Pressure-Void Ratio Curve for Sample 11

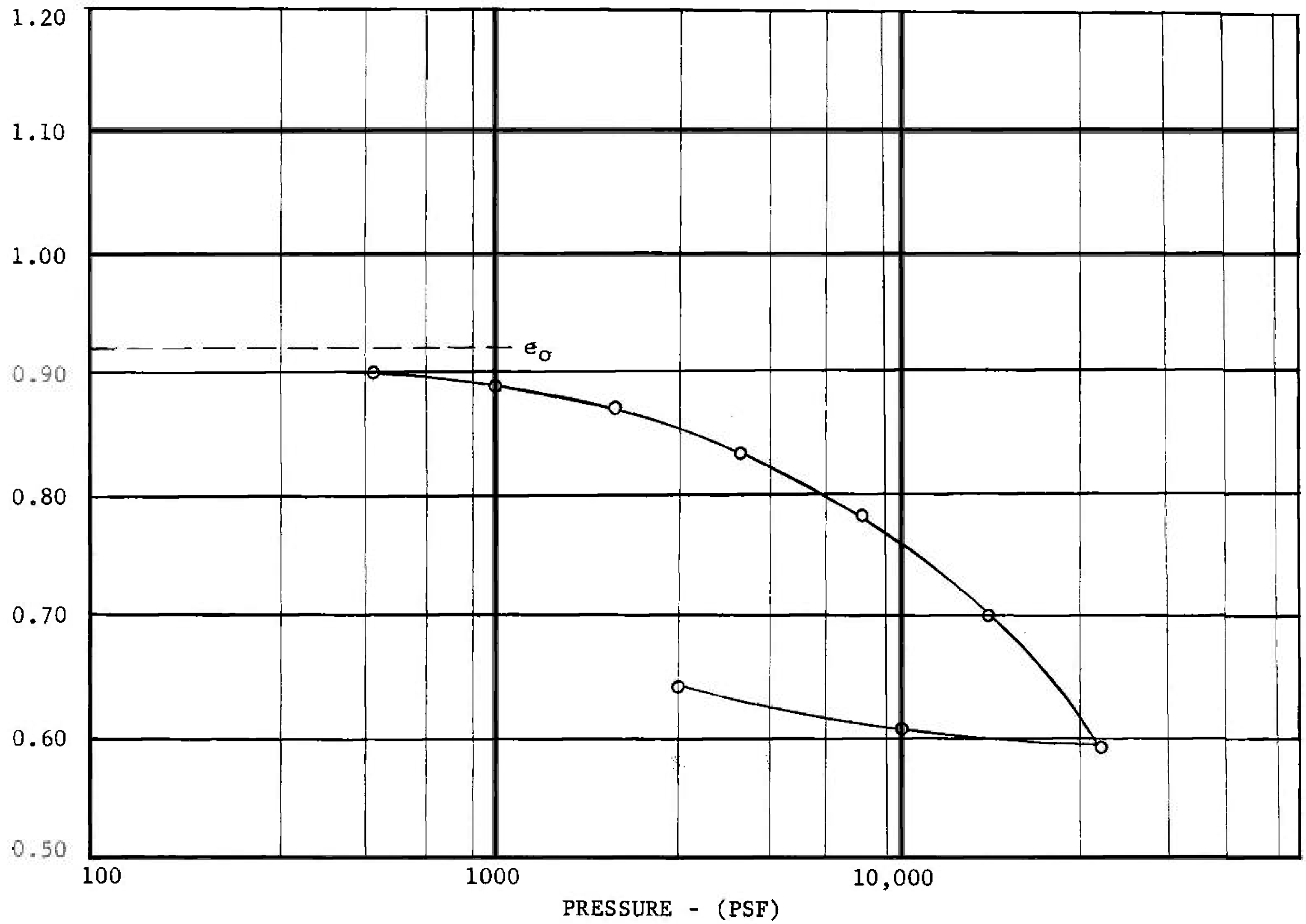

Figure 21. Pressure-Void Ratio Curve for Sample 12

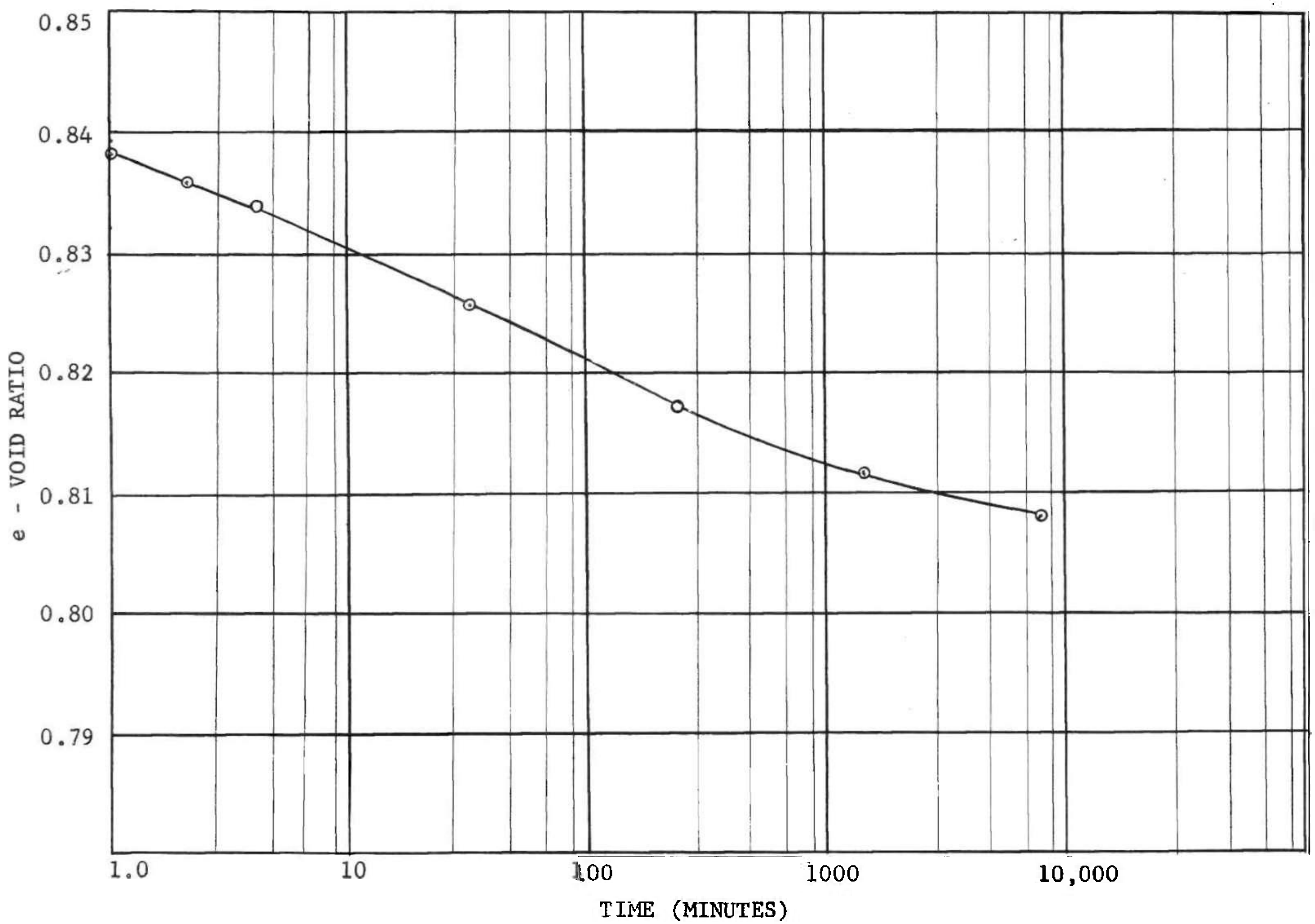

Figure 22. Time-Settlement Curve
16,000 psf for Sample 1

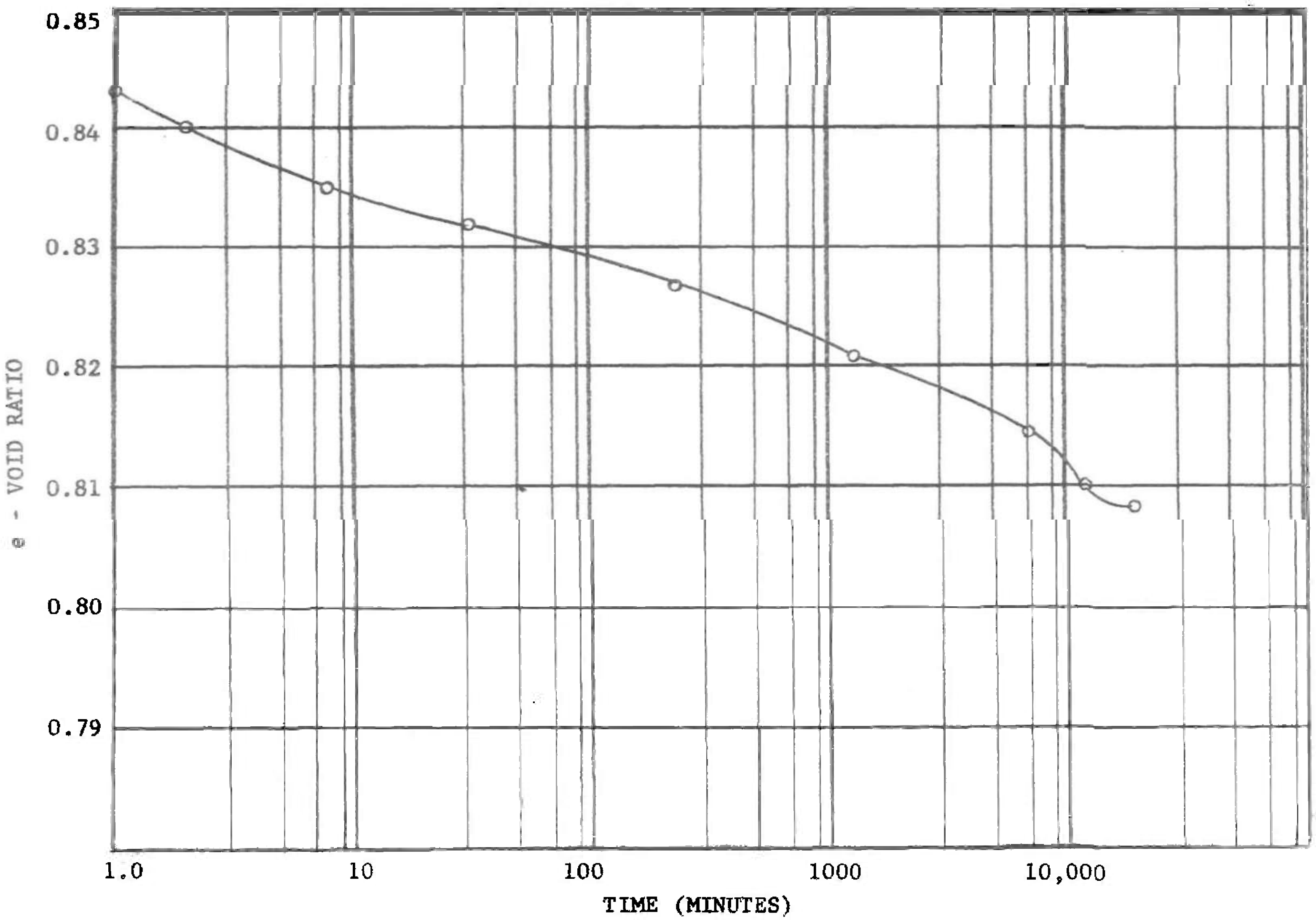

Figure 23. Time-Settlement Curve
16,000 psf for Sample 2

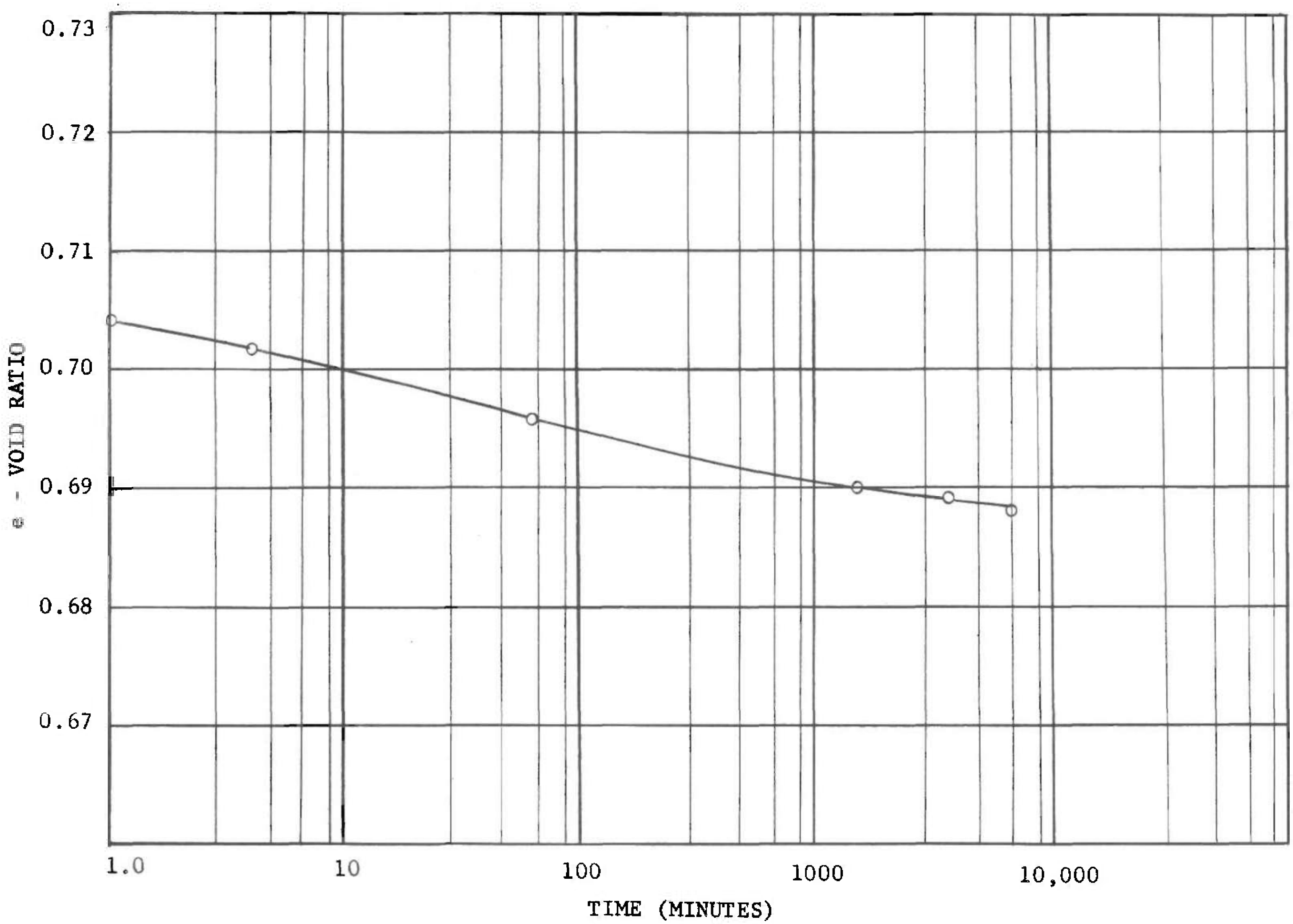

Figure 24. Time-Settlement Curve
16,000 psf for Sample 3

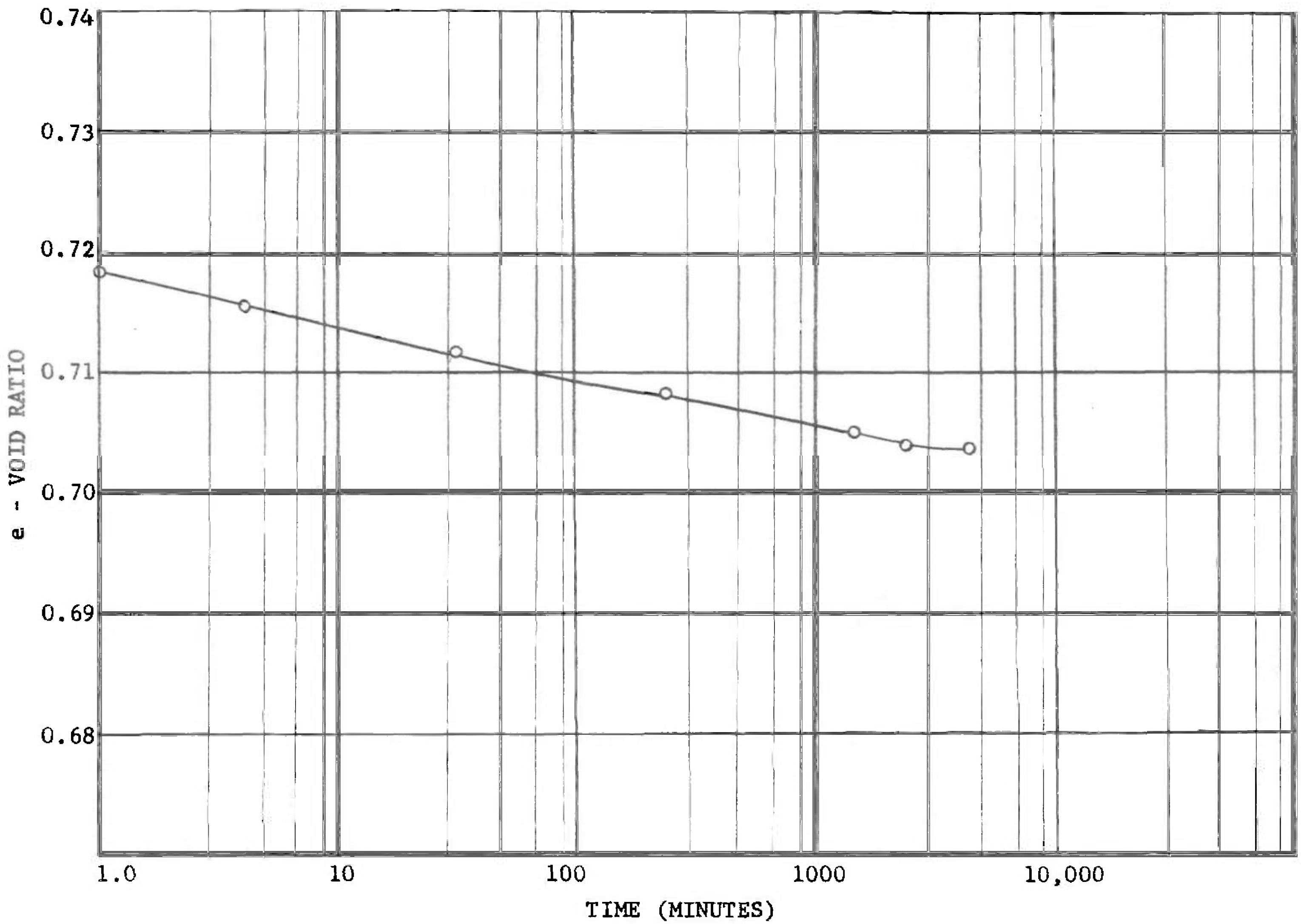

Figure 25. Time-Settlement Curve
16,000 psf for Sample 4

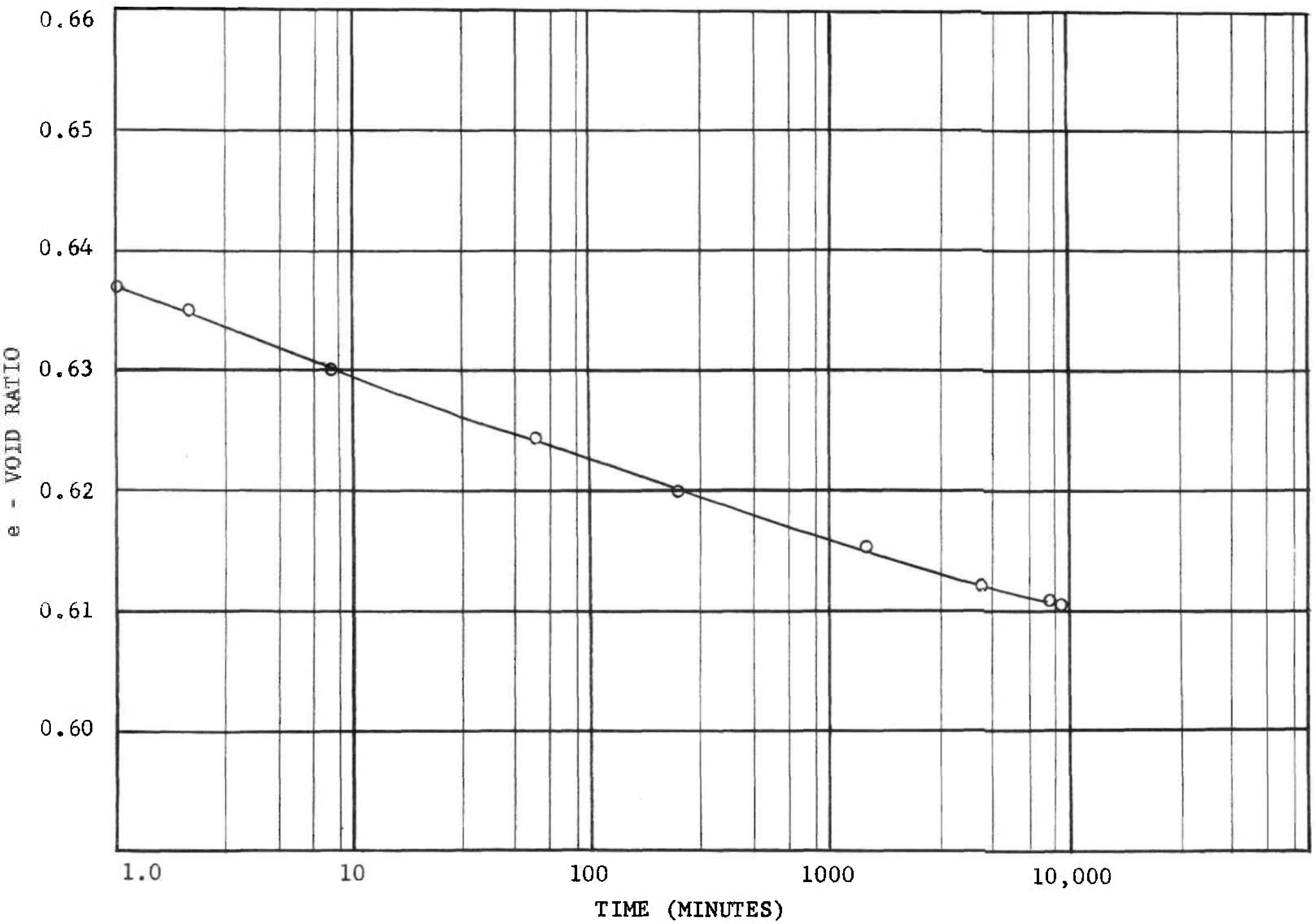

Figure 26. Time-Settlement Curve
32,000 psf for Sample 5

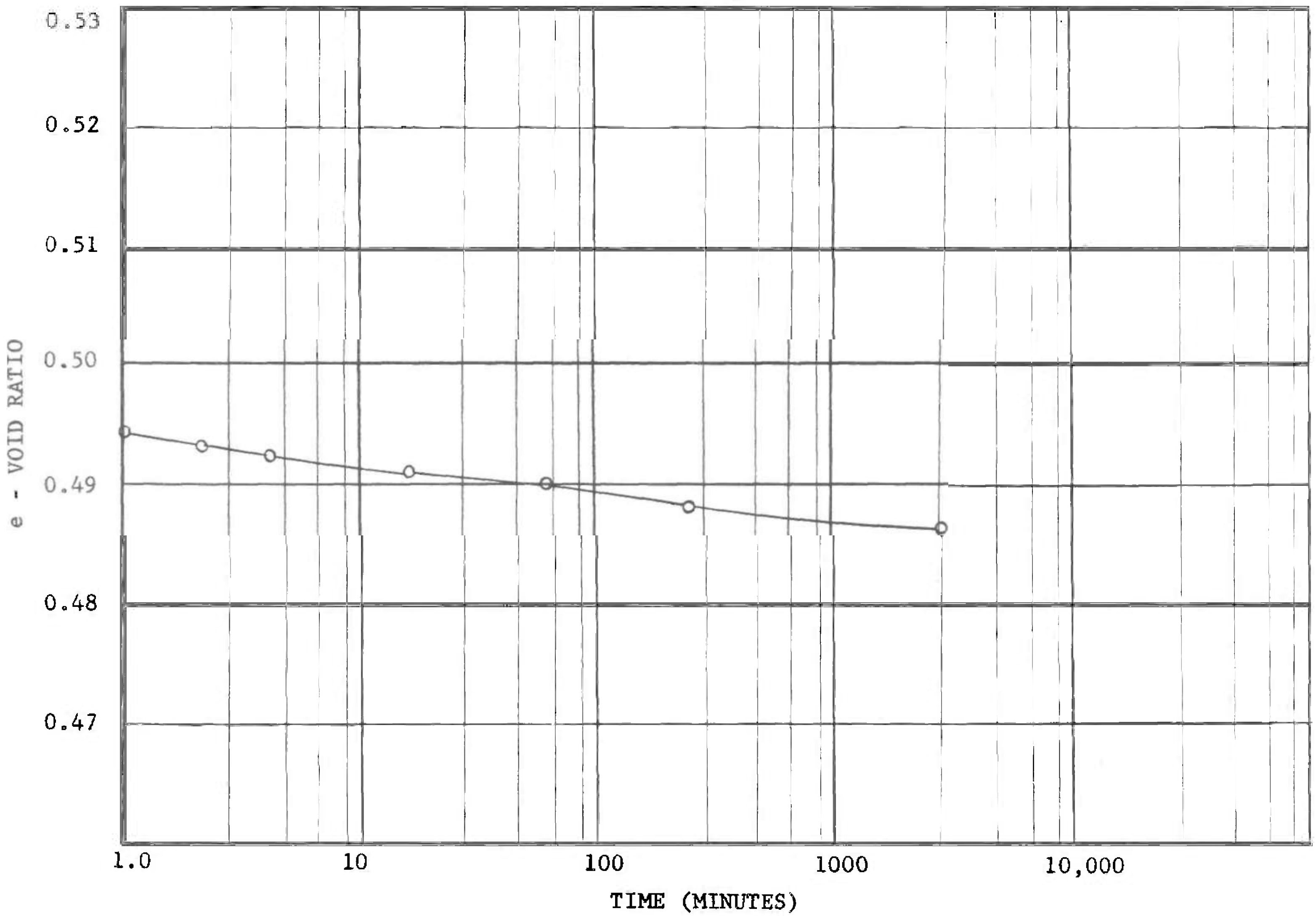

Figure 27. Time-Settlement Curve
32,000 psf for Sample 6

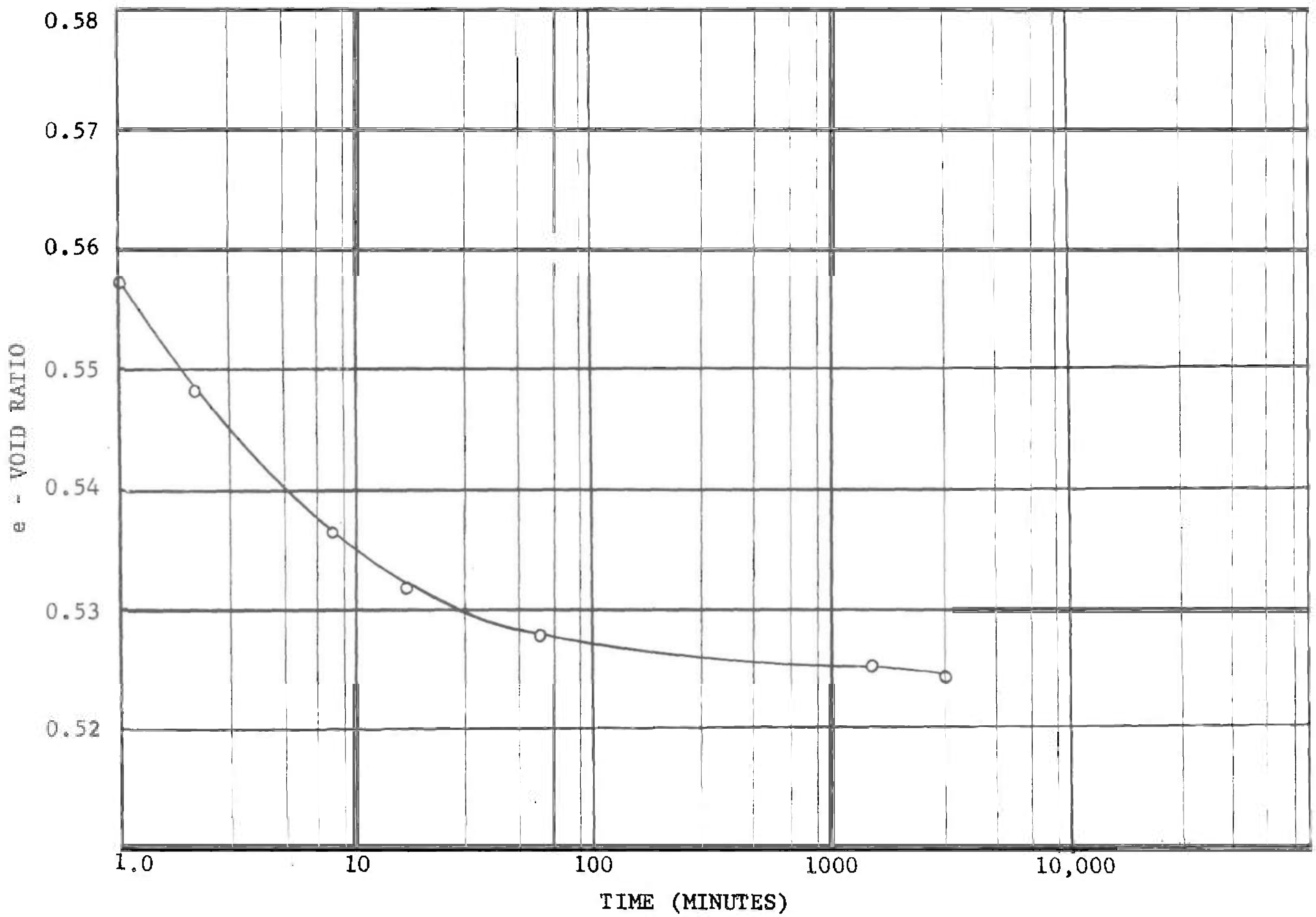

Figure 28. Time-Settlement Curve
32,000 psf for Sample 7

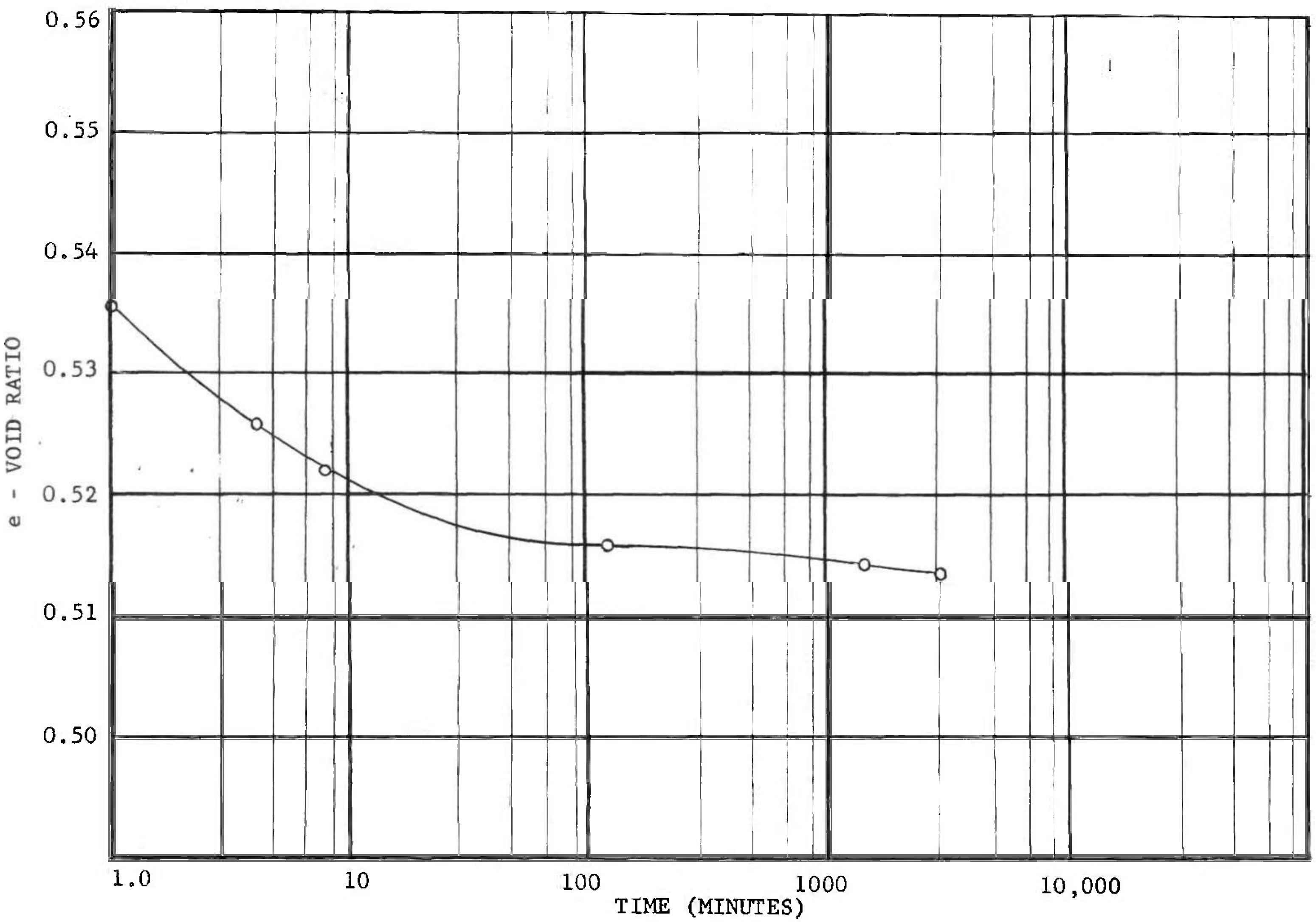

Figure 29. Time-Settlement Curve
32,000 psf for Sample 8

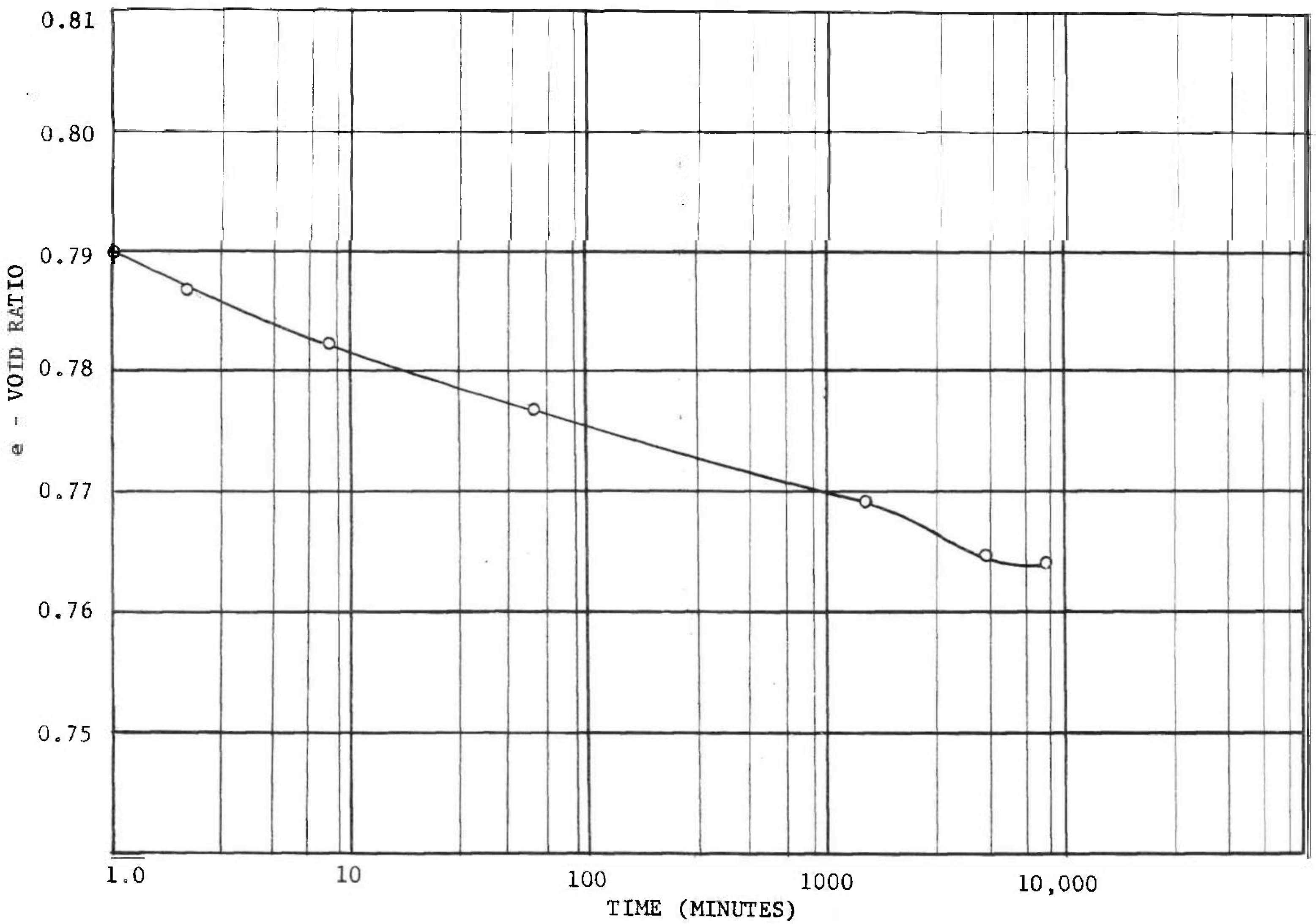

Figure 30. Time-Settlement Curve
32,000 psf for Sample 9

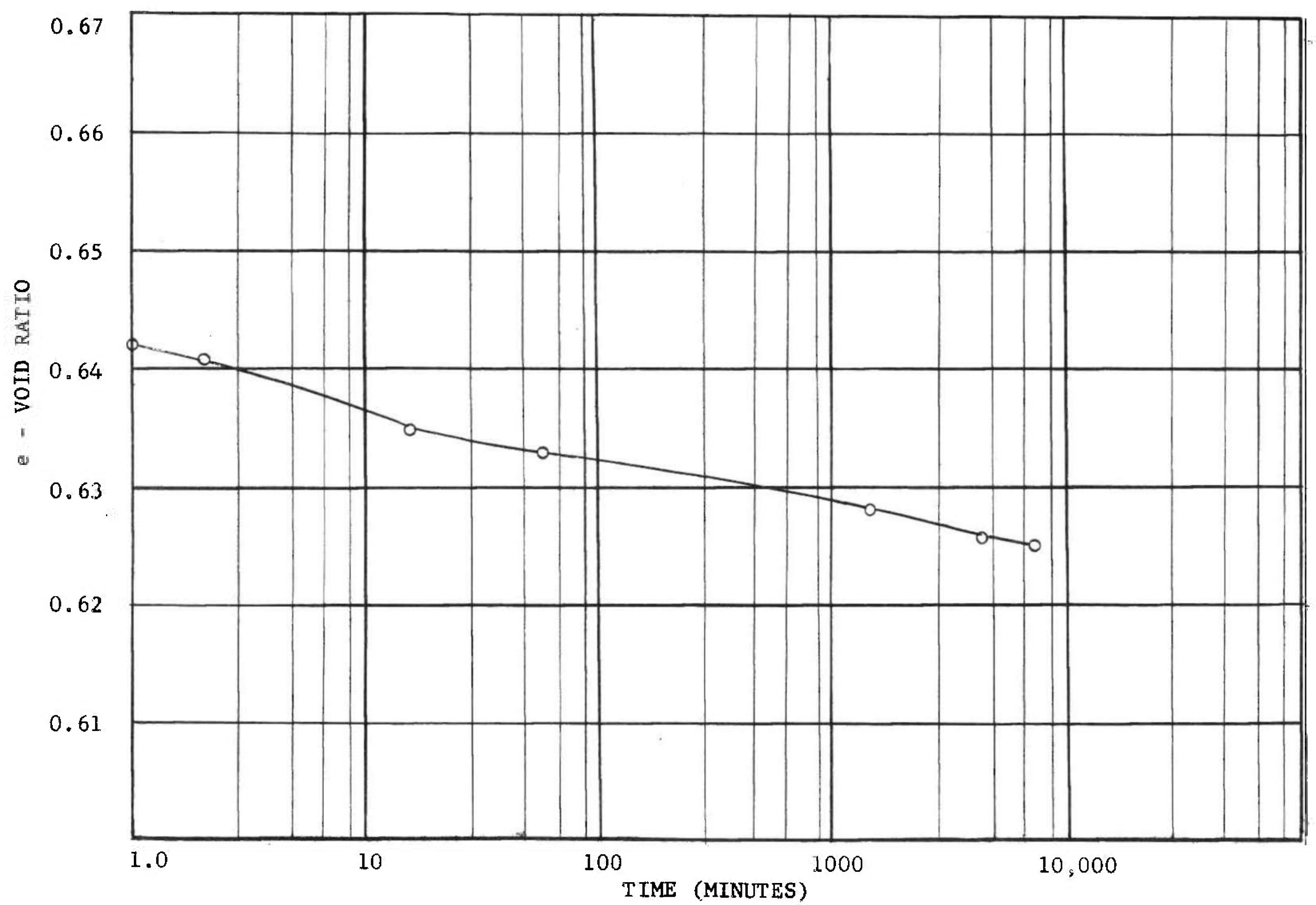

Figure 31. Time-Settlement Curve
32,000 psf for Sample 10

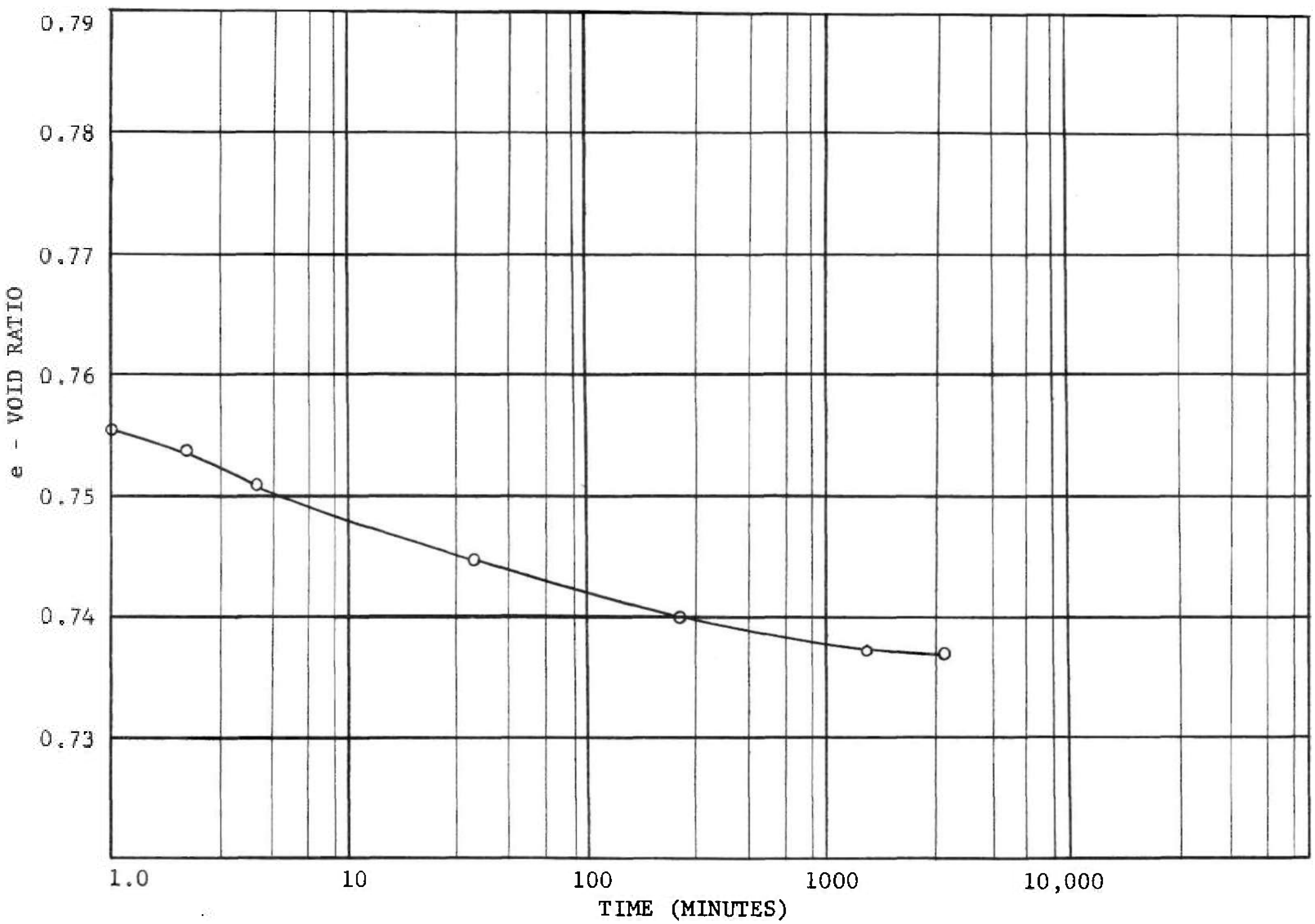

Figure 32. Time-Settlement Curve
32,000 psf for Sample 11

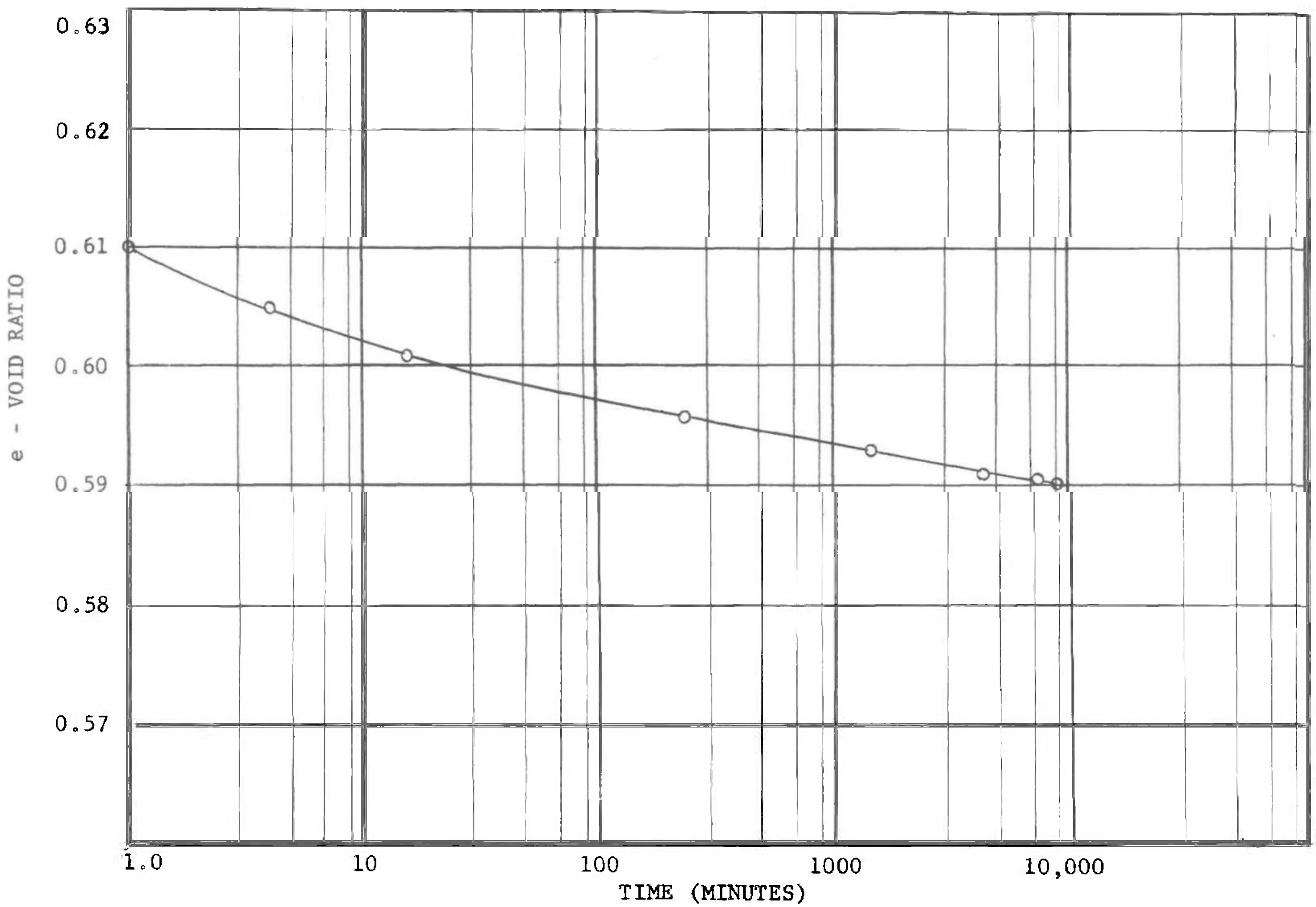

Figure 33. Time-Settlement Curve
32,000 psf for Sample 12

LITERATURE CITED

1. Stokes, W. L. and Varnes, D. J., Glossary of Selected Geologic Terms, Proc. Colorado Scientific Society, Vol. 16 (1955), Denver, Colorado, pp. 128.

2. Gilboy, G., The Compressibility of Sand-Mica Mixtures, Proceedings American Society of Civil Engineers, No. 54 (1928) pp. 555-568.

3. Tate, B. D. and Larew, H. G., The Effect of Structure on the Resilient Rebound Characteristic of Soils in the Piedmont Province of Virginia, Paper Present at Highway Research Board, Washington, Jan. 1963. (Unpublished)

4. McCarthey, D. F., Jr., and Leonard, R. J., Compaction and Compression Characteristics of Micaceous Fine Sands and Silts. Paper Present at Highway Research Board, Washington, Jan. 1963. (Unpublished)

5. Hough, B. K., Basic Soil Engineering, The Ronald Press Company, New York, 1957. pp. 26.

6. Terzaghi, K., and Peck, R. B., Soil Mechanics in Engineering Practice, John Wiley and Sons, Inc., New York, 1948. pp. 57-58.

7. Terzaghi, K., Influence of Geologic "Factors on the Engineering Properties of Sediments", Economic Geology Fiftieth Anniversary Volume. Lancaster, Pa., Economic Geology Publishing Co. (1955), pp. 570-571.

8. Sowers, G. F., Soil Problems in the Southern Piedmont Region Proceedings, ASCE, Soil Mechanics and Foundations Division, Vol. 80, Separate No. 416. New York, 1954.

9. Sowers, G. F., Engineering Properties of Residual Soils Derived from Igneous and Metamorphic Rocks, Paper presented at the Second Pan American Conference on Soil Mechanics and Foundation Engineering, Brazil (1963), pp. 8-10.

10. Sowers, G. F., Laboratory Manual for Soil Testing, Georgia Institute of Technology, Atlanta, Ga. (1955).

11. Bulletin No. MIB-104, Carpco Research and Engineering, Incorporated, Jacksonville, Florida (1959).

12. Krumbein, W. C., and Pettijohn, F. H., Manual of Sedimentary Petrography, D. Appleton-Century Company, Inc., New York (1938), pp. 320-344.

13. Iddings, J. P., Rock Minerals, John Wiley and Sons, Inc., New York (1906), pp. 24-29.

14. Chayes, F., Petrographic Modal Analysis, John Wiley and Sons, Inc., New York (1956).

15. Sowers, G. F., "Shallow Foundations", Foundation Engineering, McGraw-Hill Book Co. Inc., 1961, pp. 579-580.